Appendix A.0 CONCEPTUAL FOUNDATION AND ANALYTICAL FRAMEWORK FOR EFFECTS ANALYSIS

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Contents

A.1 CONCEPTUAL FOUNDATION FOR EFFECTS ANALYSIS

A.1.1 Purpose

A conceptual foundation is a set of scientific theories, principles, and assumptions that describe how an ecosystem functions. The conceptual foundation determines how information is interpreted, what problems are identified, and as a consequence, the range of appropriate solutions (Williams 2006). For the Bay Delta Conservation Plan (BDCP), the conceptual foundation is the scientific outline of the biological effects analysis that guides how the analysis is organized and displayed.

Lichatowich (1998) describes the value of a clear conceptual foundation as:

> *"...it is an analog to the picture that comes with a jigsaw puzzle. The picture, usually on the box lid, illustrates what all the pieces will look like when placed in their proper order. Each piece of the puzzle is a small data set containing information, which is interpreted by continually comparing or referencing back to the picture. Assembling the puzzle without the guidance of the picture or with the wrong picture would be extremely difficult if not impossible. Unfortunately, biological systems do not come with a single clear picture or conceptual foundation we can use to interpret the information contained in the various pieces of the salmon management puzzle. The conceptual foundation must be constructed by biologists using a combination of*

> *information specific to the watershed, scientific theory and reasonable assumptions."*

The BDCP is a very complex jigsaw puzzle with numerous pieces. Considerable effort and cost have been devoted to studying and describing the details on each puzzle piece. Assembling these pieces into a useful depiction of the Sacramento–San Joaquin River Delta (Delta) ecosystem requires reference to a "picture" that allow us to organize and assemble the pieces. The conceptual foundation provides that reference picture. However, as Lichatowich (1998) points out, the jigsaw puzzle metaphor is imperfect because we do not know the single overall picture that correctly describes and helps us to assemble all the pieces of the Delta. Further, that picture is constantly changing because of variation in the environment and the changing social dynamics that affect the Delta. For these reasons, the conceptual foundation for the Delta is best viewed as a hypothesis that identifies our assumptions and knowledge at this point in time. This picture of the conceptual foundation will change over time as our understanding of the Delta improves.

The BDCP conceptual foundation is a picture that allows us to assemble the scientific and management pieces into a coherent plan. The conceptual foundation applies to both aquatic and terrestrial environments, however, much of the emphasis of the BDCP is on changes to the aquatic environment and so the conceptual foundation emphasizes impacts to aquatic species. The conceptual foundation is based on the work of scientists and managers working in the Delta, Suisun Bay, Sacramento River, and San Joaquin River. It especially reflects input from the BDCP Science Advisors (BDCP Science Advisors 2007), the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and the Interagency Ecological Program Pelagic Organism Decline (POD) work group (Baxter et al. 2010). DRERIP (http://www.dfg.ca.gov/ERP/conceptual_models.asp) has produced conceptual models (referred to as the *Delta conceptual models*) for several key aquatic species and ecological processes that have been consulted and incorporated into the conceptual foundation to the extent appropriate. The BDCP conceptual foundation, however, is developed specifically to aid the analysis of the impacts of BDCP on covered fish and wildlife species.

The conceptual foundation has components relating to biological and physical structure of the Delta, environmental and biological descriptors and life history accounts of the target species. Collectively, these elements create a conceptual model of the BDCP Study Area. Related to the conceptual foundation is the analytical framework that describes the models, data and analyses that correspond to relationships described in the conceptual foundation. The Analytical Framework describes the overall analytical scheme for the effects analysis that is detailed in the methods section of each appendix. However, the conceptual foundation is developed independent of the Analytical Framework and is not driven by the availability of data or quantitative models or tools.

The conceptual foundation is organized first by its component parts. Each component is defined below and described.

A.1.2 Components

A.1.2.1 Ecological Principles

Fundamental to the conceptual foundation is a set of ecological principles suggested by the BDCP Science Advisors (BDCP Science Advisors 2007). The ecological principles are scientifically based statements that underlie Delta fish science and should influence the evaluation of BDCP. These ecological principles are based on current ecological science and the specific circumstances of the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta).

A.1.2.2 Vision

The vision articulates the purpose and desired condition of the Study Area from the perspective of the BDCP parties. It contains both ecological and sociological elements and reflects the management goals of the BDCP. To continue the jigsaw puzzle metaphor, the vision is the picture on the puzzle box as defined by the BDCP; the other components of the conceptual foundation provide a richer development of the vision and the components necessary to organize the pieces into an effective program.

A.1.2.3 Ecological Overview

The ecological overview describes the major ecological processes in the Study Area as well as a set of problem statements that describe known constraints on the system that currently preclude achievement of the vision. BDCP conservation measures should be designed to address these problem statements. The ecological overview can also be viewed as the broadest context for the effects analysis.

A.1.2.4 Ecological Structure

The ecological structure is the framework around which to construct the analysis of biological effects in the BDCP Effects Analysis (Chapter 5). It consists of the physical, chemical, and biological processes that interact to determine ecological conditions spatially and temporally in the Delta. These components provide the means to describe how the BDCP will affect the environment and thereby change the performance of covered species.

> *Normative*. The term *normative* refers to conditions describing the ideal functioning of the Delta ecosystem given the overall drivers of the system. Anthropogenic activities can further constrain the system to something other than the normative condition. For example, a normative condition for the Delta is high turbidity water even though current turbidity is reduced through anthropogenic stressors. Normative ecological functions are the flow, sediment transfer and geomorphology leading to creation and maintenance of habitat conditions supporting native fish and wildlife.

A.1.2.5 Geographic Structure

The geographic structure is the spatial organization of the analysis of BDCP covered activities and conservation measures. Covered activities occur at specific locations and affect different species and life stages. The description of the geographic structure is hierarchical to recognize drivers and stressors operating at large and small scales. The structure also is organized to consider the ways in which key environmental gradients, particularly tidal exchange, salinity, and elevation interact across the Study Area.

A.1.2.6 *Species Models*

Species models organize the available scientific knowledge of species habitat requirements, particularly as they relate to BDCP actions. The biological evaluation of the BDCP will focus on the effects of changes to the environment as a result of BDCP actions and their impact on covered species. Species models will be discussed generally in this conceptual foundation and in detail in Appendix B.

A.1.3 Ecological Principles

The BDCP ecological principles are a set of scientifically based statements that provide the overall assumptions and perspective of the BDCP effects analysis. The principles underlined below are based on the *Principles for Conservation Planning in the Delta* developed by the Bay Delta Conservation Plan Independent Science Advisors (BDCP Science Advisors 2007). The ecological principles will inform the evaluation of the BDCP conservation strategy.

1. Changes in estuarine ecosystem may be irreversible. Human activities have fundamentally altered the physical structure of the Delta and introduced numerous new species that now compete with and prey on native species (Baxter et al. 2010). These changes have produced a Delta ecosystem that is different from the historical ecosystem and will remain so even as anthropogenic stressors are relaxed. BDCP actions take place in the context of a natural-cultural system[1] that differs markedly from its pre-development condition.

2. Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea level rise) and unforeseen or rare events (e.g., the consequences of new species invasions). In other words, "Expect the unexpected." The Delta ecosystem is and will continue to be highly variable and will change in both predictable and unpredictable ways. Recovery of covered species in the Delta will require active and adaptive management that reflects new information, different circumstances and environmental change.

3. The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin Rivers into the Pacific Ocean. The effects of BDCP actions will reflect the environmental context in which they occur including the Central Valley, San Francisco Bay and Pacific Ocean.

[1] The Delta is a natural-cultural system because it contains a mixture of natural and human (cultural) elements (Williams et al. 1999). A natural-cultural system implies a vision that attempts to reconcile human needs with normative ecological functions.

4. The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The spatial and temporal variability of the Delta creates inherent uncertainties.

5. Species that use the Delta have evolved life-history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities. The fundamental changes to the Delta ecosystem as a result of human activities may be beyond the adaptive potential of native species. Habitat restoration efforts should strive to restore environmental conditions that promote normative ecosystem functions.

6. Achieving desired ecosystem outcomes will require more than manipulation of a single ecological stressor. The physical and biological complexities of the Delta ecosystem argue against simplistic single factor solutions. Restoration of ecosystem health will require more holistic approaches (Baxter et al. 2010).

7. Habitat should be defined from the perspective of a given species. Habitat is a species-based concept reflecting the physiological and life-history requirements of species. Habitat is not synonymous with vegetation type, land (water) cover type, or land (water) use type. To succeed, species require sufficient diversity, quantity, and quality of habitat to complete their life histories (Williams 2006).

8. Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem. Water quality in the Delta is affected by a variety of discharges from agricultural, industrial and urban sources that have been linked to ecological changes (e.g.,Thompson et al. 2000; Glibert 2010). The Delta environment is characterized by distinct salinity gradients that vary with managed and natural outflow and tides. Water in the Delta is typically turbid, although dams, submerged aquatic vegetation and other factors have reduced turbidity. Some or all of these conditions may adversely affect performance of native species.

9. Land use is a key determinant of the spatial distribution and temporal dynamics of flow and contaminants which, in turn, can affect habitat quality. The BDCP Study Area is a natural-cultural system with a mix of natural and human-caused features and constraints. Human actions, including the covered activities, may control and alter conditions and could affect species performance.

10. Changes in one part of the Delta may have far-reaching effects in space and time. The Delta is a system of interconnected biological and physical processes operating across multiple scales. BDCP covered activities and conservation measures are part of an integrated plan. Actions should not be considered in isolation but rather in the context of Delta ecosystem.

11. Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred. While the BDCP is limited in what it can do to reverse past undesirable responses, it will improve existing conditions

with restoration efforts that will alter the Delta environment in part to reverse changes caused by past human actions.

12. Adaptive management is essential to successful conservation. Many of these principles point to the highly variable and unpredictable nature of natural systems and the Delta in particular. Fixed management programs may fail as the system shifts and new stressors emerge. Effective management will be adaptive, accepting uncertainty as an inherent condition. An adaptive approach would require explicit management and scientific designs to implement actions.
13. Conservation measures to benefit one species may have negative effects on other species. Species are connected through the foodweb and through use of common resources. Efforts to enhance one species or a collection of desirable species may have consequences for other desirable and undesirable species.

A.1.4 Vision

The BDCP is intended achieve two goals: (1) restore and protect the ecological health of the Delta and (2) restore and protect water supplies from the Delta. Unlike past regulatory approaches, which have relied on iterative adjustments to the operations of the State Water Project (SWP) and Central Valley Project (CVP), the BDCP will prescribe actions to produce fundamental, systemic and long-term physical changes to the Delta. These changes will involve substantial alterations to water conveyance infrastructure and water management regimes in combination with extensive restoration of habitat and actions to reduce the impacts of various biological stressors. It is expected that these actions will significantly enhance Delta productivity and ecological processes so as to provide for the conservation of multiple species and natural communities, while improving water supply reliability for the export contractors. To further advance this holistic approach and enhance opportunities for success, the BDCP will accommodate and respond over time to new information and greater scientific understanding of the Delta.

BDCP envisions the Delta as a system with a mix of natural and cultural features that supports normative ecological functions in the context of human activities, including the export of water to support human needs. *Normative*, in this context, refers to features (norms) characterizing the intrinsic condition of the Delta including the functions and processes that make the Delta a unique ecological system. For example, the normative biological community consists of native, co-evolved fish and wildlife species; the normative condition for the Delta is a complex of open water, sloughs and wetlands dominated by a snow-melt hydrograph. The normative condition provides a reference against which to compare existing or future conditions. An ecologically healthy Delta is defined for the BDCP to be one that promotes ecological functions to contribute to recovery and perpetuation of native species, including those listed under the Federal Endangered Species Act (ESA). These listed species are representative of the normative biological community, and it is assumed that restoration of conditions consistent with the needs of listed species also will provide benefits to other native, co-evolved species.

To achieve this vision, the BDCP will implement a comprehensive ecological restoration program that addresses stressors across the ecosystem, including actions related to water conveyance, habitat, and measures dealing with other stressors. The program will be based on the best available science and ecological tenets to achieve the following:

- An increase in the quality, availability, spatial diversity, and complexity of aquatic habitat within the Delta.
- New opportunities to restore the ecological health of the Delta by modifying the water infrastructure to convey water around the Delta by reducing reliance on conveyance of water through artificial and natural channels in the Delta to export pumping plants in the southern Delta.
- Actions that directly address key ecosystem drivers rather than manipulation of Delta flow patterns alone.
- Improved connectivity among aquatic habitats, improved migration and movement of covered fish among habitats, and conditions for the dispersal of planktonic material (organic carbon), phytoplankton, zooplankton, macroinvertebrates, and fish eggs and larvae.
- Improved synchrony between environmental cues and conditions and the life history of covered fish and their food resources within the BDCP Study Area, including the hydrologic seasonal synchrony within the watershed, seasonal water temperature gradients, salinity gradients, turbidity, and other environmental cues.
- Reduced direct mortality and other stressors on the covered fish and the aquatic ecosystem within the Delta.
- Improved habitat conditions for covered fish in upstream river reaches, within the Delta, and downstream within the low-salinity zone (LSZ) of the estuary in Suisun Bay through the integration of water operations with physical habitat enhancement and restoration.
- A reduction in adverse effects on terrestrial wildlife and plants resulting from implementation of measures to benefit aquatic species.
- Expanded extent and enhanced functions of existing natural communities and habitat of covered wildlife and plants that is permanently protected.
- Restored habitat to expand the populations and distributions of covered wildlife and plant species.
- Reliance, to the extent possible, on natural physical habitat and biological processes to support and maintain covered species and their habitat.

The comprehensive program should substantially improve conditions in the Delta for native fish and wildlife species. The plan includes provision for changing how water is moved in the Delta by constructing a new diversion point on the Sacramento River to be used as an alternate method of conveying water to the Central Valley Project (CVP) and State Water Project (SWP) pumps in the south Delta (south Delta pumps). A conveyance structure would be constructed consisting of five intake structures on the Sacramento River (north Delta intake) to collect water that would be conveyed to the south Delta pumps through a tunnel or canal. This structure combined with existing pumps is referred to as the *dual conveyance structure* because it allows water to be exported from either the new north Delta intake or the existing south Delta pumps depending on water conditions and operational criteria for protection of fish. The dual conveyance structure provides an alternative to the south Delta pumps for water exports and creates a more flexible system to achieve the goals of the BDCP.

The dual conveyance structure addresses two key biological concerns with current water operations in the Delta that may affect native fish species (U.S. Fish and Wildlife Service 2008). First, the use of the south Delta pumps can alter the natural hydrodynamics and reverse the flow of water in the south Delta (reverse flow means that water moves south toward the pumps through Old and Middle River (OMR) rather than the normative prevailing northwestward flow out of the San Joaquin River). Second, the pumps entrain and kill juvenile and adult fish and other biota. Taking water exports from the Sacramento River through the new BDCP dual conveyance structure would reduce the use of the south Delta pumps thereby reducing entrainment, and provide appreciable restoration of normative San Joaquin River flow conditions in the south Delta. With respect to the goal of restoring water supplies, the new conveyance structure will provide the flexibility to restore supplies while improving conditions for the fisheries.

BDCP also envisions substantial restoration of tidal marsh and other aquatic habitat that have been lost to agricultural and other development. The program will restore or protect up to 113,000 acres of aquatic and terrestrial habitat including 65,000 acres of tidal marsh in the Delta and improve floodplain environments on the Sacramento River, especially the Yolo Bypass. These will approximately double the amount of tidal and intertidal wetland habitat now available in the Delta. Habitat restoration will return previous wetlands and floodplain environments, providing key habitat for life stages of native fish species such as delta smelt, Sacramento splittail, and salmonids. The restored wetlands will also provide habitat for a variety of resident and migrant waterfowl as well as key mammal, reptile and amphibian species. Restoration of large portions of the Delta to tidal habitat will affect the hydrodynamics and water quality in immediately surrounding channels and, in some cases channels distant from the restoration site, by increasing the tidal prism and reducing the tidal range. The reduction in contaminants, such as pesticides and herbicides that will result from restoring habitat on agricultural lands, is expected to interact synergistically with improvements in organic and nutrient input from restored tidal marsh and floodplains to benefit the aquatic foodweb.

The BDCP also includes conservation measures that address other factors potentially affecting covered fish species. These factors, collectively referred to as *other stressors*, go beyond issues associated with water operations and physical habitats to address toxic contaminants, other water quality issues (e.g., dissolved oxygen), nonnative species, hatcheries, harvest, and non project diversions that are individually and collectively affecting the productivity of the Delta. The inclusion of these measures into the BDCP reflects the comprehensive nature of the approach to conservation that underlies the BDCP. Conservation measures addressing other stressors include:

- Methylmercury management conservation to minimize the potential for habitat restoration actions, implemented under the BDCP, to increase the bioaccumulation of methylmercury in covered and other native species.
- Nonnative aquatic vegetation control conservation to control the growth of Brazilian waterweed (*Egeria densa*), water hyacinth (*Eichhornia crassipes*), and other nonnative submerged and floating aquatic vegetation in BDCP tidal habitat restoration areas.
- Dissolved oxygen management to maintain dissolved oxygen concentrations above levels that impair covered fish species in the Stockton Deep Water Ship Channel during periods when covered fish species are present.
- Predator control to reduce local effects of predators on covered fish species by conducting focused predator control in high predator density locations.
- Non-physical fish barriers to improve the survival of outmigrating juvenile salmonids by using non-physical barriers to redirect them away from channels in which survival is lower.
- Development of hatchery and genetic management plans to develop and implement hatchery and genetic management plans to minimize the potential for genetic and ecological impacts of hatchery reared salmonids on wild salmonid stocks.
- Harvest enforcement to reduce illegal harvest of Chinook salmon, Central Valley steelhead, green sturgeon, and white sturgeon in the Delta, bays, and upstream waterways through increased enforcement of fishing regulations in the Delta and bays.
- Evaluation of conservation hatcheries to establish new and expand existing conservation propagation programs for delta and longfin smelt.

The BDCP will also conserve terrestrial natural communities and habitat for covered terrestrial wildlife and plant species that are adversely affected by the aquatic conservation actions. Specifically, the BDCP could achieve the following for natural communities and terrestrial covered species:

- Conserve, restore, and provide for the management of representative natural and seminatural landscapes;
- Establish reserves that provide for conservation of covered species within the BDCP geographic area and linkages to adjacent habitat outside the Study Area;
- Protect and maintain habitat areas that are large enough to support sustainable populations of covered species;
- Incorporate in the reserves, a range of environmental gradients and high habitat diversity to provide for shifting species distributions in response to changing circumstances; and

- Sustain the effective movement and interchange of organisms between habitat areas in a manner that maintains the ecological integrity of the system of BDCP conservation lands.

Adverse effects to terrestrial natural communities and covered wildlife and plants are largely driven by the amount, type, timing, and location of wetland restoration, the primary purpose of which is to restore habitat for covered fish species. Smaller adverse effects on some species also may result from the construction of new facilities to support the new water operations. The amount of conservation provided for each of the covered species is proportional to the effects on that species from BDCP covered activities.

The BDCP includes additional conservation actions to minimize adverse effects to covered terrestrial species and to contribute to their recovery in the Plan Area. Where conservation measures at the ecosystem and natural community level may not adequately conserve a covered wildlife or plant species, the BDCP includes species-specific conservation measures to ensure appropriate outcomes for the species.

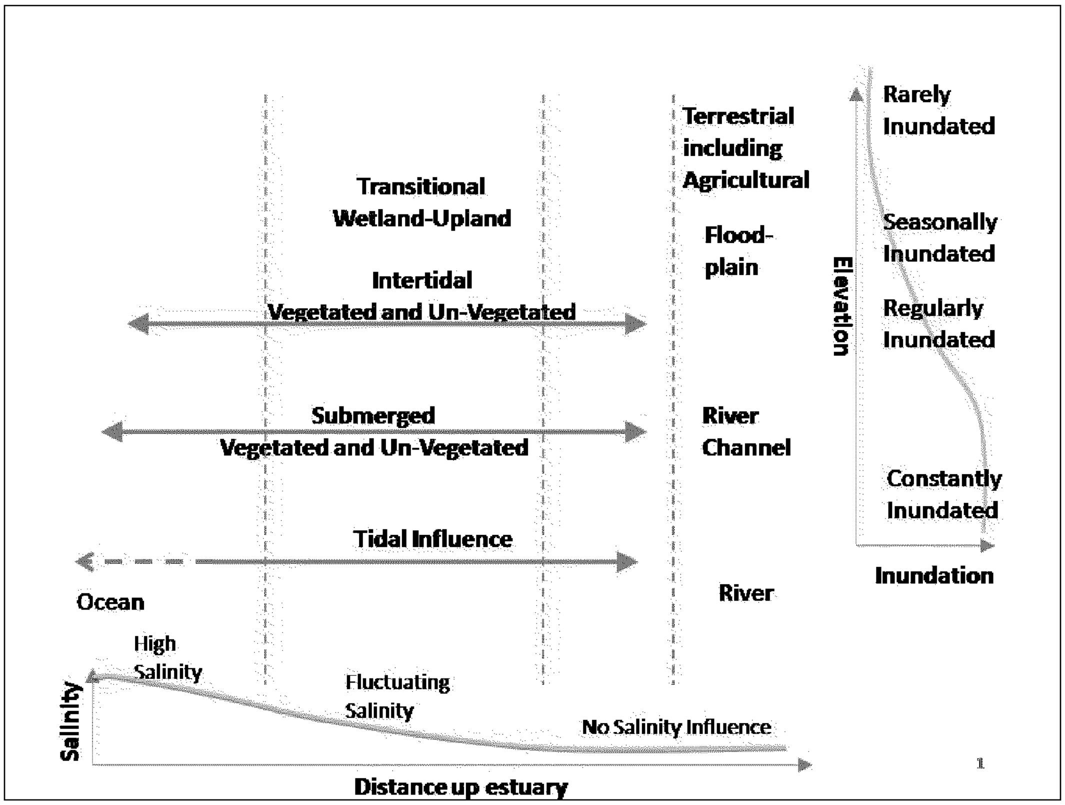
A.1.5 Ecological Overview

The Delta is part of the overall San Francisco estuary, the largest estuary on the U.S. Pacific Coast (Sommer et al. 2007). The estuary has three distinct parts: San Francisco Bay, the Delta, and lower portions of the Sacramento and San Joaquin Rivers. The BDCP Plan Area encompasses the legal Delta, the southern portion of the Yolo Bypass and Suisun Bay and Marsh. The BDCP Study Area also includes substantial portions of the Sacramento River and San Joaquin River watersheds as affected by BDCP actions. San Francisco Bay connects to the Pacific Ocean through the Golden Gate and therefore has a more marine character. The Delta is the estuary and tidal marsh at the confluence of the Sacramento and San Joaquin Rivers. The Sacramento River enters from the north and the San Joaquin River from the south to drain the California Central Valley.

The Delta is the nexus of freshwater and marine, and aquatic and terrestrial environments. Ecological conditions in the Delta are defined by the way in which environmental gradients interact across these environments. Two of the most influential gradients in the Delta are: (1) tidal exchange and salinity, which are influenced by distance from the ocean, and (2) the extent of water inundation influenced by elevation along with tidal and riverine flows (BDCP Science Advisors 2007; Moyle et al. 2010) (Figure A-1).

Tidal exchange and salinity produce a gradient that can be delineated into four zones from ocean to rivers: (1) high salinity with tidal exchange, (2) fluctuating salinity with tidal exchange, (3) fresh water with tidal exchange, and (4) fresh water with no tidal exchange. The borders of these zones are dynamic and depend on Delta inflows, the range of oceanic tides (mainly spring vs. neap), and regional weather.

The elevation gradient produces four zones (Figure A-1): (1) constantly inundated, (2) inundated and exposed on tidal time scales, (3) seasonally inundated, and (4) infrequently inundated. Although the elevations are fixed, at least on short time scales, the zones of inundation vary according to water levels, which depend on the interaction of river flows and the tide as well as atmospheric pressure and winds. Structures such as levees, barriers, and tidal gates modify gradual gradients of tidal exchange and salinity, creating abrupt shifts in environmental conditions (e.g., in elevation or salinity), and subsidence increases the degree of inundation during floods. These alterations can disrupt the transport and exchange of chemical and biological materials along these gradients.



Source: (BDCP Science Advisors 2007).

Figure A-1. Horizontal and Vertical Gradients That Control Environmental Conditions in the Delta

Historically, the Delta was a complex of channels and flooded marsh formed by tules and other plants occurring at the interface of freshwater inflow and marine waters (Kimmerer 2004). Since the mid–nineteenth century, the Delta has been modified extensively through diking and draining of marsh lands that removed 95 percent of the historical wetlands in the estuary (Sommer et al. 2007) and by management of inflow due to upstream water storage projects. The estuary now contains numerous introduced or invasive species that make up the majority of species and most of the biomass of aquatic species (Cohen and Carlton 1998). This has altered the biological community with impacts to native species as evidenced by the decline in pelagic fish species (Baxter et al. 2010).

The decline of State- and Federally listed fish, including delta smelt, has had dramatic impacts on water management and exports in the Delta (Miller 2011). Although the abundance of Delta fish species varies widely from year to year, the decline in abundance of several pelagic species around 2002 was alarming to fishery managers. This decline has been termed the *pelagic organism decline* or POD. The reasons for POD are complex and not completely understood (Sommer et al. 2007; Baxter et al. 2010) but have been the focus of numerous scientific studies. In response to the decline in pelagic fish species, an inter-agency work group was formed to oversee studies and summarize current information related to the POD (Baxter et al. 2010).

In their most recent synthesis, the POD work group proposed the hypothesis that the decline in pelagic fish species is an indicator of a fundamental regime shift in the Delta ecosystem (Baxter et al. 2010). The POD conceptual model incorporates the notion that the effects of environmental changes initially can be absorbed by the resilience of an ecological system but accumulate to eventually cause a more-or-less abrupt shift in the character and functioning of the system (Ludwig et al. 1997). Thus, the cause of the shift in Delta fish species may not be the proximal circumstances but rather the accumulation of changes over a longer time frame.

The current POD conceptual model links the long-term decline and recent collapse of pelagic fishes to multiple and often interactive drivers whose effects can be grouped into four major categories: prior fish abundance (e.g., stock-recruitment effects), habitat effects (e.g., loss of key species habitat), top-down effects (e.g., predation and entrainment), and bottom-up effects (e.g., food availability and quality) (Baxter et al. 2010). Top-down effects refer to mortality from predation and entrainment by water diversions while bottom-up effects refer to food availability and quality. Bottom-up effects have received significant attention in recent years because of increasing evidence that changes in the pelagic foodweb have reduced both the quantity and quality of food available to pelagic fishes (Jassby et al. 2003). Compared to other estuaries, primary productivity and phytoplankton biomass in the upper San Francisco estuary (measured by chlorophyll-a concentration) is low and has declined over the last four decades (Jassby et al. 2003). This long-term decline has been linked to shifts in nutrient ratios and concentrations (especially increasing ammonium concentrations associated with changes in sewage treatment), grazing by the overbite clam (*Corbula amurensis*), and changes in composition of the phytoplankton community (Jassby et al. 2003; Baxter et al. 2010; Glibert 2010). These changes have been shown to be linked to changes in zooplankton communities and overall declines in food availability for pelagic fishes. The sharpest declines have been observed among calanoid copepods, a primary prey for the early life stages of pelagic fishes (Kimmerer 2004). Long-term trends in pelagic fish populations show a correlation to these changes in food supply (Glibert 2010). Thus, bottom-up food limitation is likely an important driver influencing long-term fish trends in the upper estuary and has been identified as a potentially significant factor in the recent POD. However, it is likely not the sole driver of the POD based on analysis of the long-term monitoring data and review of the recent time series data associated with the POD (Baxter et al. 2010).

In summary, the Delta ecosystem is the nexus of freshwater and marine environments driven by regional precipitation, geology, and marine boundaries. Human land use has fundamentally altered the Delta ecosystem and is now an important driver of ecological processes. The driver of human land use may have forced a regime shift in the system and fundamentally altered biological community and ecological processes. This change may be exacerbated by regional and global climate change that may affect precipitation and marine drivers. BDCP is an ecological program designed to address many of the proximal constraints on native fish and wildlife communities; however, the ultimate success of the program will reflect the character of the new Delta regime.

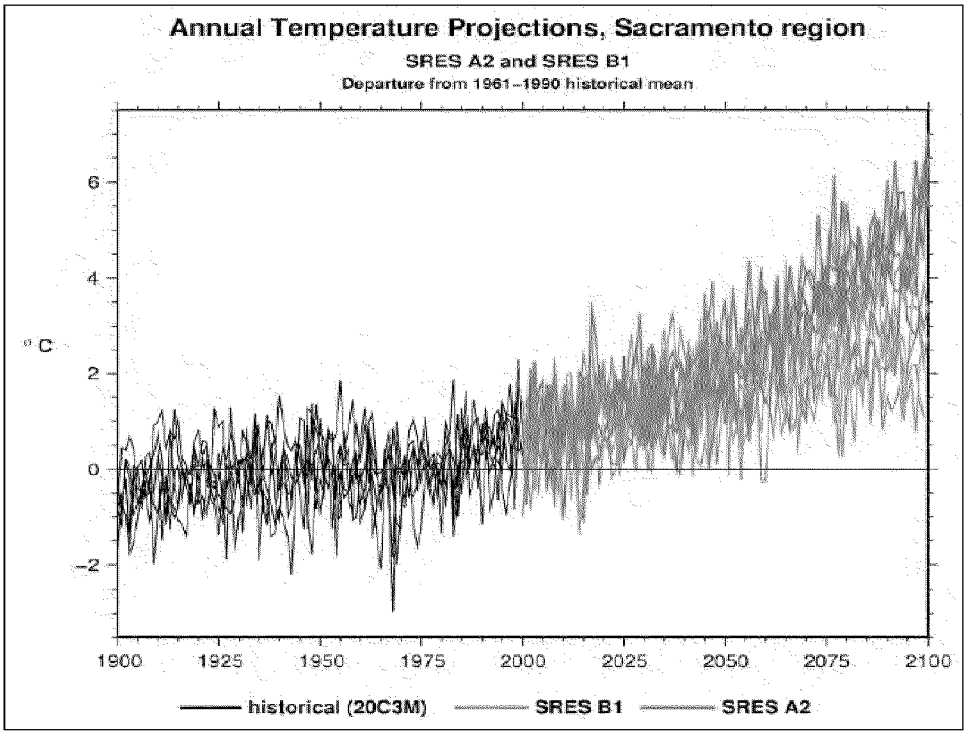
A.1.5.1 Climate Change

Over the BDCP implementation period, regional climate is expected to change in response to changes in climate globally (Pachauri and Reisinger 2007). In California, climate change is expected to increase air and water temperature, change precipitation patterns, raise sea level, and change salinity patterns across the Study Area (Hayhoe et al. 2004). Climate change can be expected to affect hydrologic conditions and management (Willis et al. 2011) and can affect the success of BDCP actions such as habitat restoration (Battin et al. 2007).

Climate change is expected to affect particularly the following conditions.

A.1.5.1.1 Temperature

Observed climate and hydrologic records indicate that more substantial warming has occurred in the Study Area since the 1970s (Figure A-2). The current suite of global climate change models, when simulated under future greenhouse gas emission scenarios, exhibit warming globally and regionally over California. Global climate models used by the California Climate Action Team (CAT) for their 2009 scenarios project a mid-century temperature increase of about 1°C to 3°C (1.8°F to 5.4°F) and end-of-century increase from about 2°C to 5°C (3.6°F to 9°F) (Cayan et al. 2009).



Source: Cayan et al. 2009.

Figure A-2. Simulated Historical and Future Annual Temperature Projections for the Sacramento Region

A.1.5.1.2 Precipitation

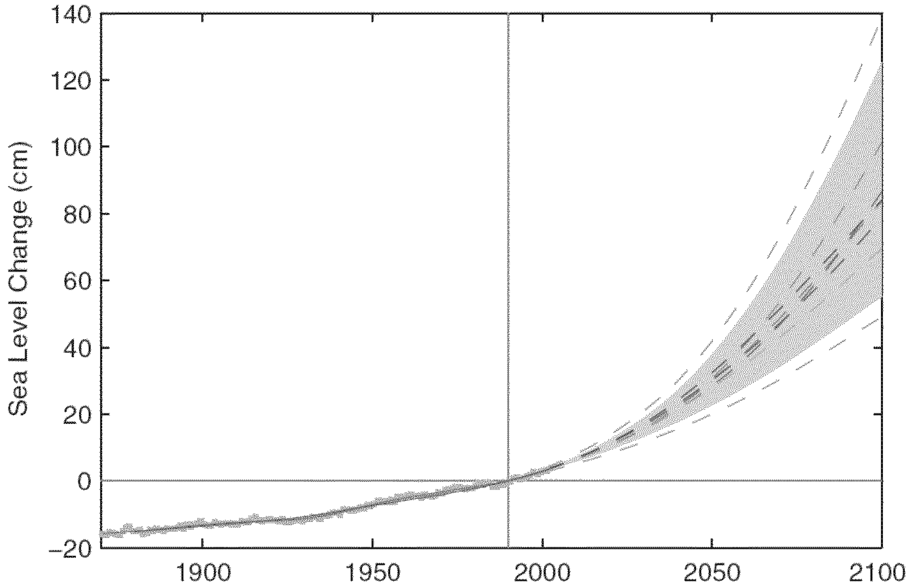
Precipitation in California is characterized by extreme variability over seasonal, annual, and decadal time scales. For this reason, projections of future precipitation are more uncertain than those for temperature. While it is difficult to discern strong trends from the full range of climate projections, the CAT analysis generally indicated a drying trend in the twenty-first century (Cayan et al. 2009). Changes in precipitation not only address total precipitation but also the form of the precipitation and the mix of rain and snowpack accumulation. Even for hydrologic model simulations with mean precipitation virtually unchanged, there were large impacts on snowpack accumulation, runoff, and soil moisture.

A.1.5.1.3 Sea Level Rise

Global and regional sea levels have been increasing steadily over the past century and are expected to continue to increase throughout this century. Over the past several decades, sea level measured at tide gages along the California coast has risen at rate of about 17–20 centimeters (cm) per century (Cayan et al. 2009).

In addition to overall sea level rise, tidal amplitude is expected to increase as a result of climate change (Jay 2009). Modeling and trend analysis indicate that on average tidal amplitude along the West Coast has increased by about 2.2% per century with San Francisco Bay showing larger increases. Amplitude increases may be greater inland than in coastal areas.

In the future, sea levels are projected to increase globally at a more rapid rate as a result of thermal expansion of water in the oceans due to global warming, changes in the freshwater input to the oceans from melting of glaciers and ice sheets, and changes in water storage on land (Figure A-3) (Ramsforf 2007). For the scenarios selected for the CAT report, sea level rise in California by 2050 is projected to be 30–45 cm (12–18 inches) higher than 2000 levels. Ramsdorf (2007) suggests end-of-century sea level rise in the range of 50–150 cm (20–59 inches).



Source: Ramsforf 2007.

Figure A-3. Past Global Mean Sea Level and Future Mean Sea Level Based on Global Mean Temperature Projections

BDCP will not directly affect climate change or regional adaptation to climate change. However, several of the core elements of the BDCP, such as Delta marsh habitat, upstream anadromous fish habitat, reservoir and conveyance facility management, and water quality, are likely to be affected by climate change. Figure A-4 highlights some potential changes to these core elements under a future with climate change.

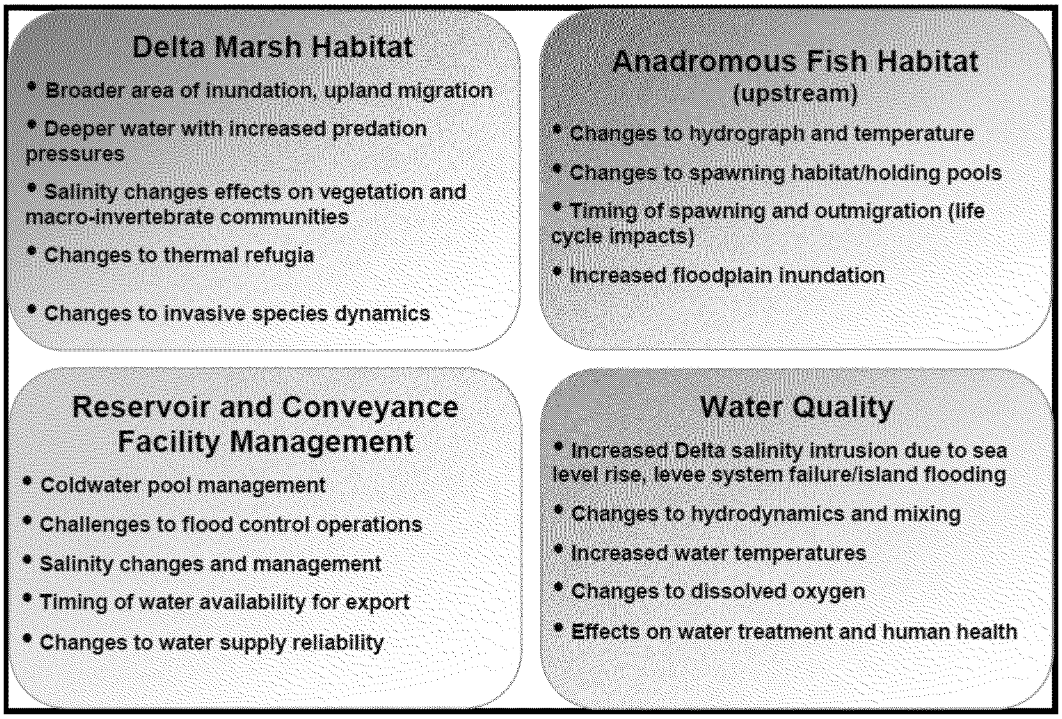


Figure A-4. Depiction of Interactions of Projected Regional Climate Change on BDCP Conservation Measures

A.1.6 Ecological Structure

The premise of this conceptual foundation is that the BDCP will alter the physical and biological environment of the Delta, which in turn will affect biological performance (abundance, persistence, and fitness) of species. The performance of a species in an environment is the result of characteristics of the habitat shaped by natural and anthropogenic factors (Southwood 1977; Peterson 2003).

The ecological structure of the BDCP is summarized in Figure A-5 in which biological potential of the Delta (species productivity, abundance and diversity) is depicted as concentric circles defined by large-scale factors termed *drivers*. Regional climate, geology, marine conditions and biogeography set the *intrinsic potential* of the system that defines the Delta as a unique ecological feature. Over the 50-year duration of the BDCP, climate is expected to change at local, regional, and global scales as a result of human and natural causes[2]. The Delta is a natural-cultural system that has been inherently altered by human activities (Ecological Principle 1) creating an *adjusted potential* of the system within the context of the larger-scale natural drivers. The adjusted potential defines the maximum potential of the system given the fundamental, and likely irreversible, environmental changes resulting from human development of the area. The

[2] Although the BDCP is not expected to directly affect climate, expected shifts in climate may affect the expected outcomes of the program.

current level of human activities constrains biological potential below the adjusted potential and defines the *current potential*. Covered activities of BDCP are a sub-set of all human constraints on the system; BDCP activities are intended to relax these constraints and define a *future potential* for the system.

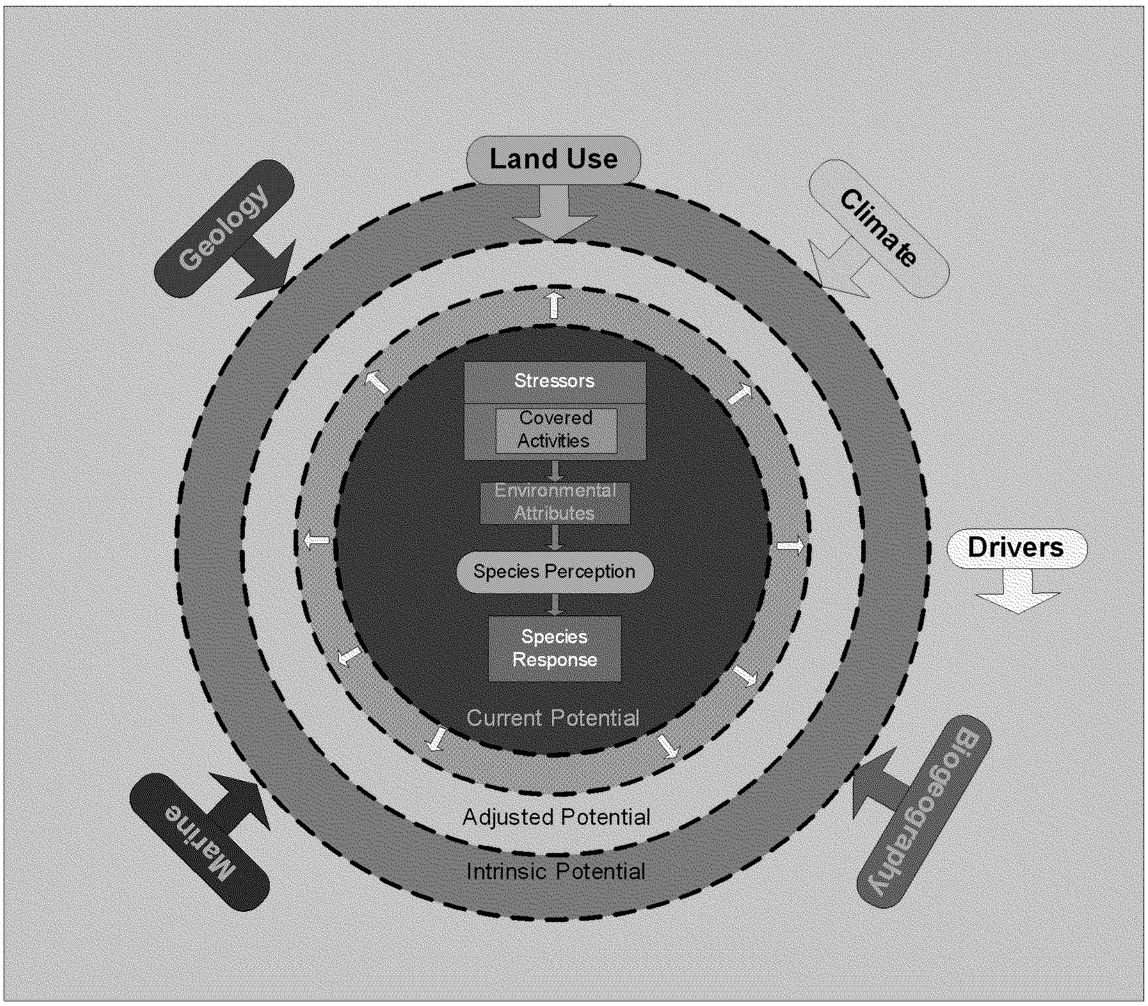


Figure A-5. Overall Conceptual Ecological Model of the Delta As Affected by the BDCP

The ecological structure of the BDCP effects analysis will use the following terms adopted from the DRERIP, supplemented by additional terminology.

A.1.6.1 *Drivers*

Drivers are large-scale features of the system that determine the possibilities and constraints on the environment in the Study Area. Primary drivers are broad categories such as climate, biogeography, geology and marine. Secondary drivers are characteristics within these broad categories. For example, climate is a primary driver with precipitation and temperature being secondary drivers that are affected by climate (Table A-1).

Table A-1. Primary and Secondary Drivers Setting the Intrinsic Potential of Conditions in the Bay-Delta

Primary Drivers	Secondary Drivers
Climate	Precipitation
	Temperature
Marine	Tides
	Salinity
Geology	Topography
	Sediment sources
Biogeography	Terrestrial Vegetation
	Terrestrial invertebrate species
	Terrestrial vertebrate species (e.g., birds)
	Aquatic plants (phytoplankton and vascular)
	Aquatic invertebrate species (zooplankton and mollusks)
	Aquatic vertebrate species (i.e. fish)

A.1.6.2 *Environmental Attributes*

Environmental attributes are the features used to describe the environment and are believed to affect species performance. Examples are flow, temperature, turbidity, toxics, substrate, submerged aquatic vegetation, and large wood structure. Human actions, including BDCP conservation measures, act on the environmental attributes to affect ecological conditions and species performance. The list of environmental attributes can be quite extensive and is independent of the needs of particular species.

A.1.6.3 *Processes*

Processes shape features of the environment (described by attributes) to create ecological functions and emergent behavior of the ecosystem such as species response. For example, observed water temperature at any point and time is the result of one or more processes linking solar energy, flow, input temperature, and other attributes. The relationship between attributes and processes is captured in individual conceptual models as well as quantitative and qualitative models used in the analysis described in subsequent appendices.

A.1.6.4 *Habitat*

To persist and thrive, a species must experience habitat of sufficient quality and quantity across its life history to permit successful reproduction, rearing, and survival to maturity. The species response to the environment as affected by the condition of attributes (including how they are affected by stressors) that produce outcomes measured by population capacity, productivity, abundance, and diversity over time. The condition of the environmental attributes determines the quality and quantity of habitat for the species. Ecological principle 7 captures the idea that habitat is a species concept; habitat the suite of physical, chemical, and biological factors determining species abundance and persistence over time (Hayes et al. 1996). For example, water temperature is an environmental attribute that becomes a factor of habitat suitability when evaluated with reference to the needs of life stages of key species such as delta smelt. The outcome of a change in temperature attributable to a management action is to increase or decrease a biological performance measure (e.g., abundance).

Nobriga (2008) described the basis for fish-habitat relationships for Delta fish species. His conceptual model for fish-habitat linkages is a useful set of elements that create habitat for various fish species (Table A-2).

Table A-2. Attributes of Habitat for Delta Fish Species

Hydro-dynamics	Water constituents transport
	Salinity
	Fish and zooplankton transport
Water Quality	Dissolved oxygen
	Suspended sediments and turbidity
	Water temperature
	Chemical contaminants
Structural Components	Beaches and shorelines
	Floodplains
	Submerged aquatic vegetation (SAV)
	Tidal marshes
Biotic Interactions	Trophic interactions (food availability and growth)
	Competition
	Predation
Source: Nobriga 2008.	

These attributes are controlled by intrinsic drivers and anthropogenic stressors that include physical and biological processes that control species performance and define habitat suitability (Peterson 2003).

A.1.6.5 *Stressors and Enhancers*

Environmental attributes that modulate, influence, or control the suitability of habitat for species and life stages are referred to as *stressors*, when they decrease habitat suitability, or *enhancers*, when they increase habitat suitability for the species. Stressors and enhancers are thus species-focused concepts. The same condition for an environmental attribute (e.g., a water temperature of 26°C) can be a stressor for some species (e.g., Chinook salmon) and an enhancer for others (e.g., largemouth bass). Each species and life stage has a unique perception of the environment, reflecting its life history and physiological needs. The condition of environmental attributes at any point in time or space is defined by the overall drivers (at regional and local scales) and by human actions, including the BDCP conservation measures.

BDCP conservation measures address conditions across the BDCP Study Area and are expected to change the condition of numerous environmental attributes relative to the current or baseline condition within and across years and across multiple spatial scales. The effects analysis will evaluate how the altered environment is perceived by the covered species and translated into changed species performance.

Stressors and enhancers are organized into six categories that correspond to categories of BDCP conservation measures (Table A-3). These stressor/enhancer categories relate to appendices in this HCP where they are discussed in detail. The stressor/enhancer categories include specific actions and constraints that are addressed by BDCP covered activities. The stressor of entrainment, for example, is affected by the dual conveyance system because of operation of the south Delta pumps and north Delta intakes. Stressors can be related to habitat conditions for species to affect species performance (Table A-3).

Table A-3. Categories and Examples of Stressors Affecting Covered Fish Species

Appendix	**Stressor/Enhancer**	**Cause**	**Habitat Elements from Nobriga (2008)**
D. Entrainment	Direct mortality at water diversion points	Project pumps and other in-Delta diversions, including power plants	
E. Flow-Salinity	Altered hydrograph or flow pattern, changed distribution of salinity	Water management including water export and channelization of the watershed	Water constituents transport, Salinity, Fish and zooplankton transport
	Stranding	Water management	
F. Water Quality	Water temperature, Dissolved oxygen, pollutants	Pollutant releases from urban, agricultural and industrial sources	Chemical contaminants
G. Habitat	Key habitat for life stages	Diking and draining of wetlands and floodplains; Alteration of hydrograph	Beaches and shorelines, floodplains, tidal marshes
H. Ecological	Food supply	Changes in biological community, nutrient ratios and competition	Trophic interactions (food availability and growth); Competition
	Predation	Introduced species, structures or submerged aquatic vegetation, changes in nutrient ratios	Suspended sediments and turbidity, Predation, Submerged aquatic vegetation (SAV)
Others	Illegal harvest	Unaccounted for harvest	
	Construction and maintenance	BDCP construction activities	

The concept of the ecological structure is illustrated in Figure A-6 using the example of the distribution and amount of environmental types, specifically intertidal wetlands. The drivers that create and maintain the amount of intertidal wetlands in the Delta are geology (topography), marine (tides, salinity), precipitation (flow), and land use (human footprint on the environment). Human activities change the amount of intertidal wetlands either negatively, by diking and draining, or positively, by restoration actions. A covered species, delta smelt for example, perceives the change in the amount of intertidal wetlands based on its life history needs and habitat requirements. Because intertidal wetlands are key habitat for delta smelt spawning, an increase in the amount of intertidal wetlands (e.g., through Conservation Measure 4) is perceived as an enhancer of overall habitat suitability. Contrarywise, the loss of intertidal wetlands would be viewed as a stressor on delta smelt leading to a decrease in overall habitat suitability. Another covered species such as Chinook salmon would perceive these changes quite differently. Because intertidal wetlands are not extensively used by Chinook salmon, the change would be viewed neutrally (except insofar as wetlands influence food supplies used by juvenile Chinook salmon).

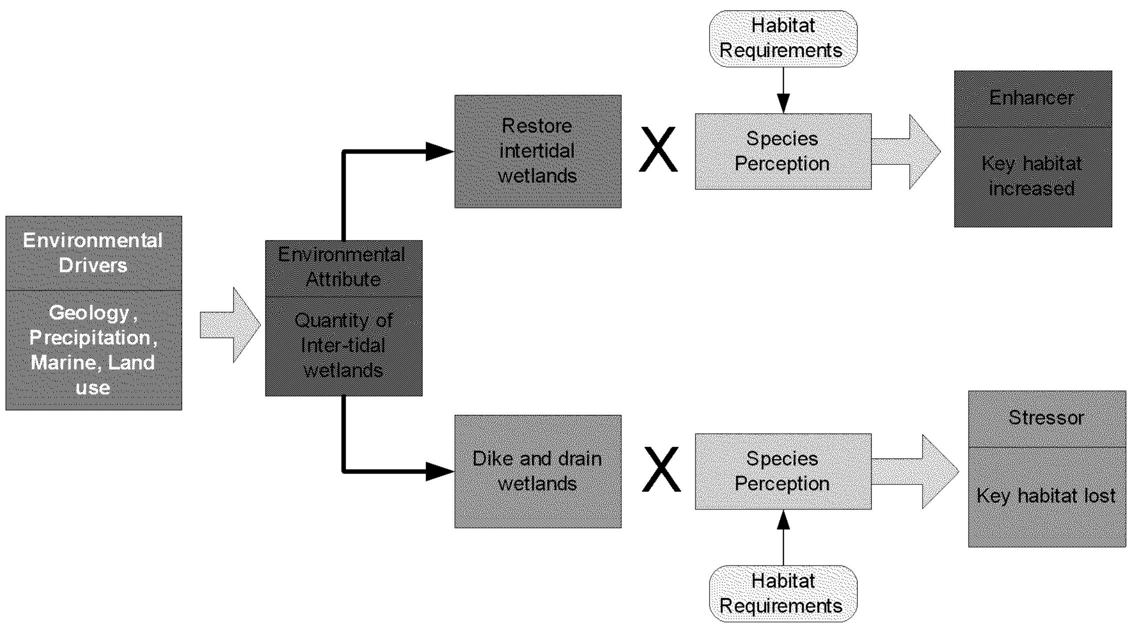


Figure A-6. Example Relationship between Elements of the BDCP Conceptual Foundation

A.1.7 Geographic Structure

The BDCP affects conditions and species across a wide array of geographies and environments with varying mixtures of stressors, environments, and species. Assessment of the impacts of individual actions and stressors is enhanced by considering them within a geographic structure that reflects the bio-geographical structure of the Delta and its tributaries. Structure and function of ecological systems are often described hierarchically (O'Neill et al. 1986); a hierarchical structure is particularly applicable to estuarine species encompassing a variety of physical and biological features (Peterson 2003). Larger-scale areas can constrain performance of smaller-scale areas. In turn, the performance at any level reflects the performance of smaller-scale features. A hierarchical structure for the BDCP is developed as follows (Table A-4):

- *The BDCP Study Area* (Figure A-7). This is the area where physical changes attributable to the BDCP have the potential to affect covered fish species. Included are the Sacramento River upstream to Keswick Dam, the San Joaquin River upstream to Friant Dam, tributaries downstream of SWP and CVP dams (Clear Creek, Feather River, American River, and Stanislaus River), and the BDCP Plan Area (see below).
- *The BDCP Plan Area* (Figure A-8). This is the portion of the Bay-Delta where major BDCP restoration actions would occur and includes the legal Delta, Suisun Bay, Suisun Marsh, and the Yolo Bypass north of Interstate 80.
- *Geographic regions*. These are clear, large-scale areas that can be distinguished hydraulically, ecologically, and geomorphologically. Regions include terrestrial and aquatic environments. The Study Area is divided into three regions: The Sacramento River watershed, San Joaquin River watershed, and the BDCP Plan Area as described above.
- *Geographic subregions* (Figure A-4). Subregions are broad geographic and hydrologically distinct areas that are relevant to the life history of Delta fish and wildlife species. Subregions include both terrestrial and aquatic resources. Within the BDCP Plan Area, the subregions are based largely on hydrodynamic subregions used by Stoms (2010) that were interpreted from a graphic conceptual model developed by the DRERIP team (J. Burau, U.S. Geological Survey, unpublished data). Outside the Plan Area, subregions include tributary reaches below dams that prevent fish passage and that may experience indirect effects from BDCP-related activities such as changed release schedules.
- *Conservation Zones* (Figure A-9). The BDCP Plan Area is also subdivided into 11 conservation zones to facilitate the design of habitat protection and restoration elements of the conservation strategy. These conservation zones were designed based on differences in landform, land cover, and land use. These zones are a useful tool for the effects analysis relative to the terrestrial natural communities and covered species.

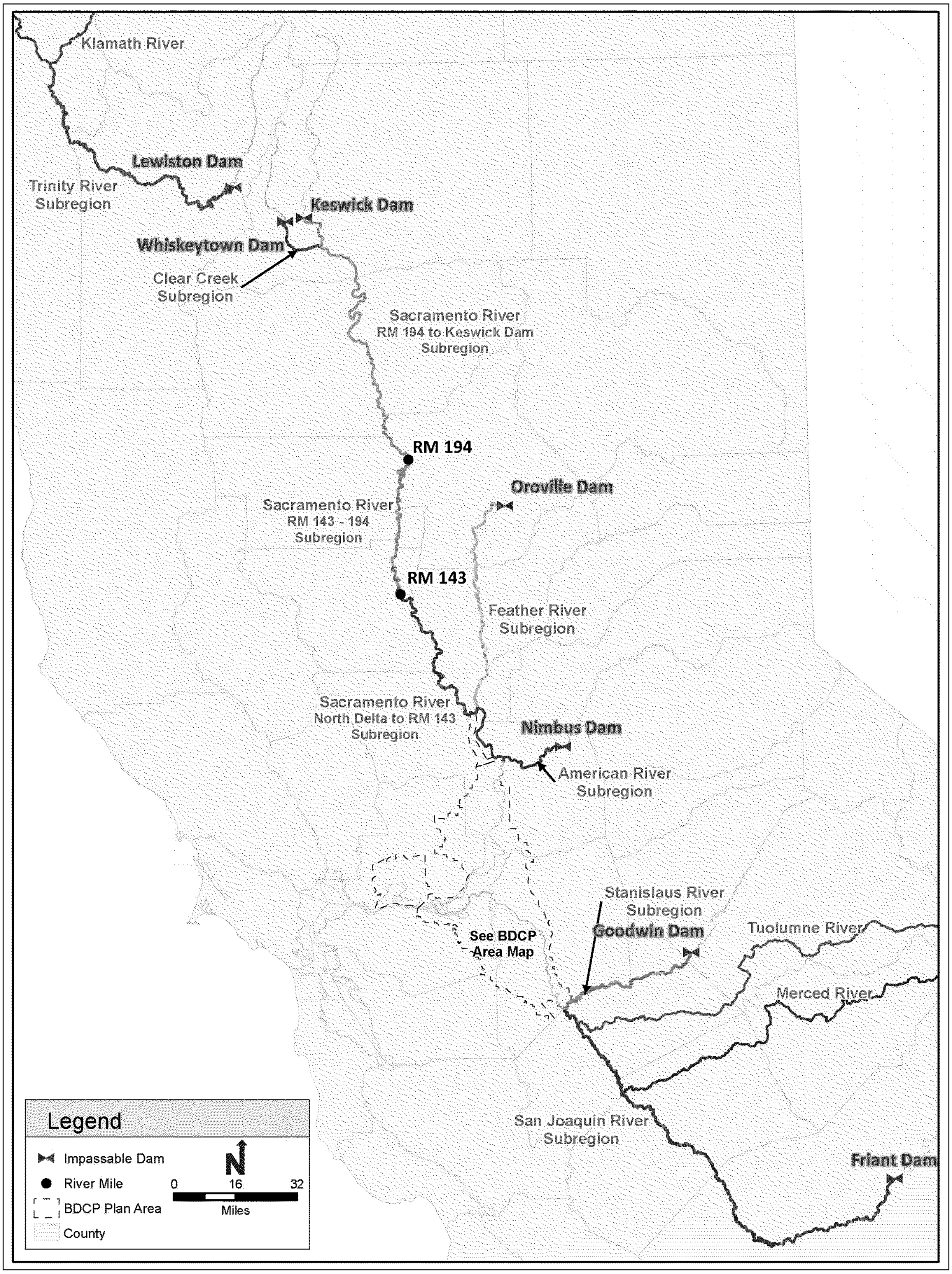


Figure A-7. BDCP Study Area

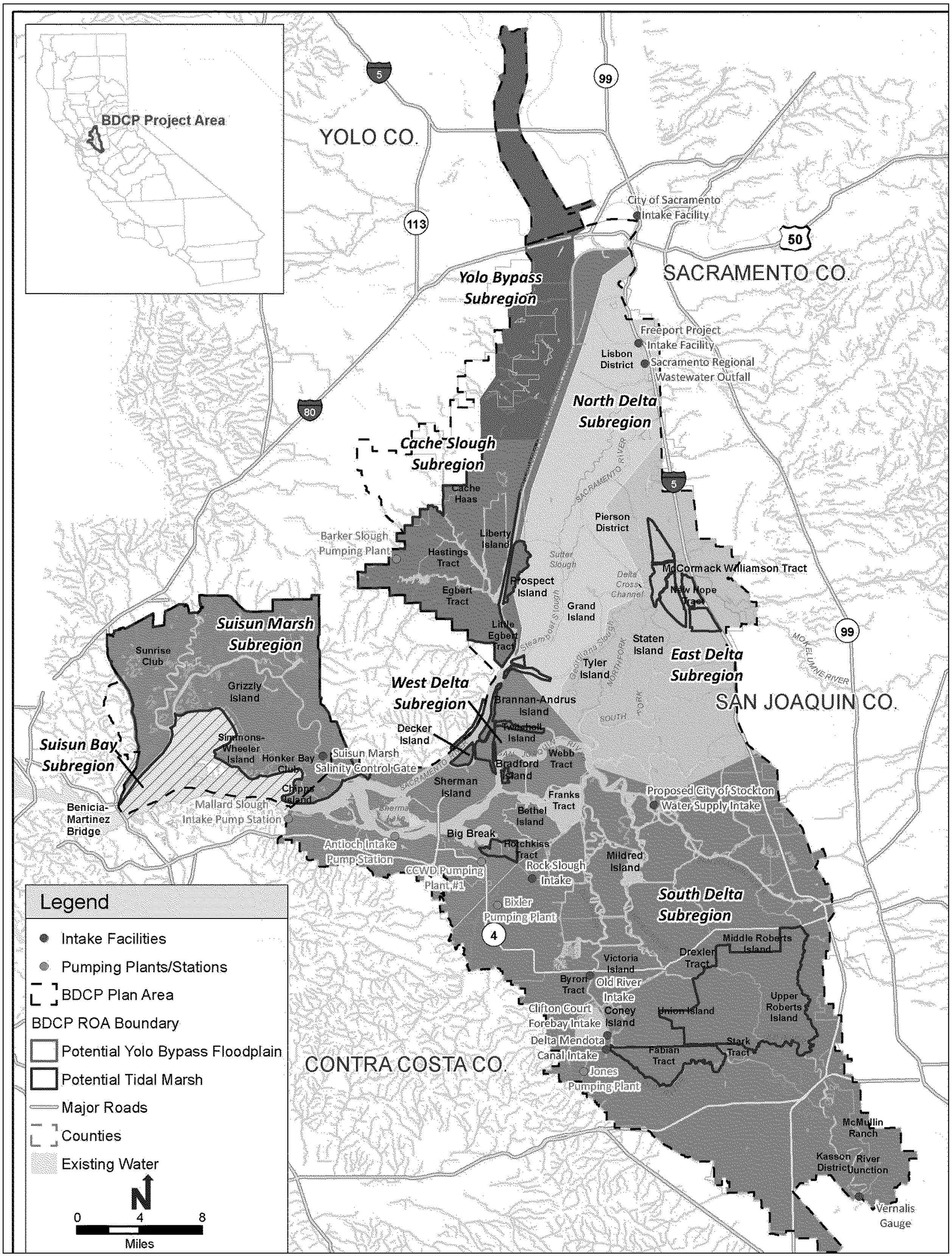


Figure A-8. BDCP Subregions within the Delta

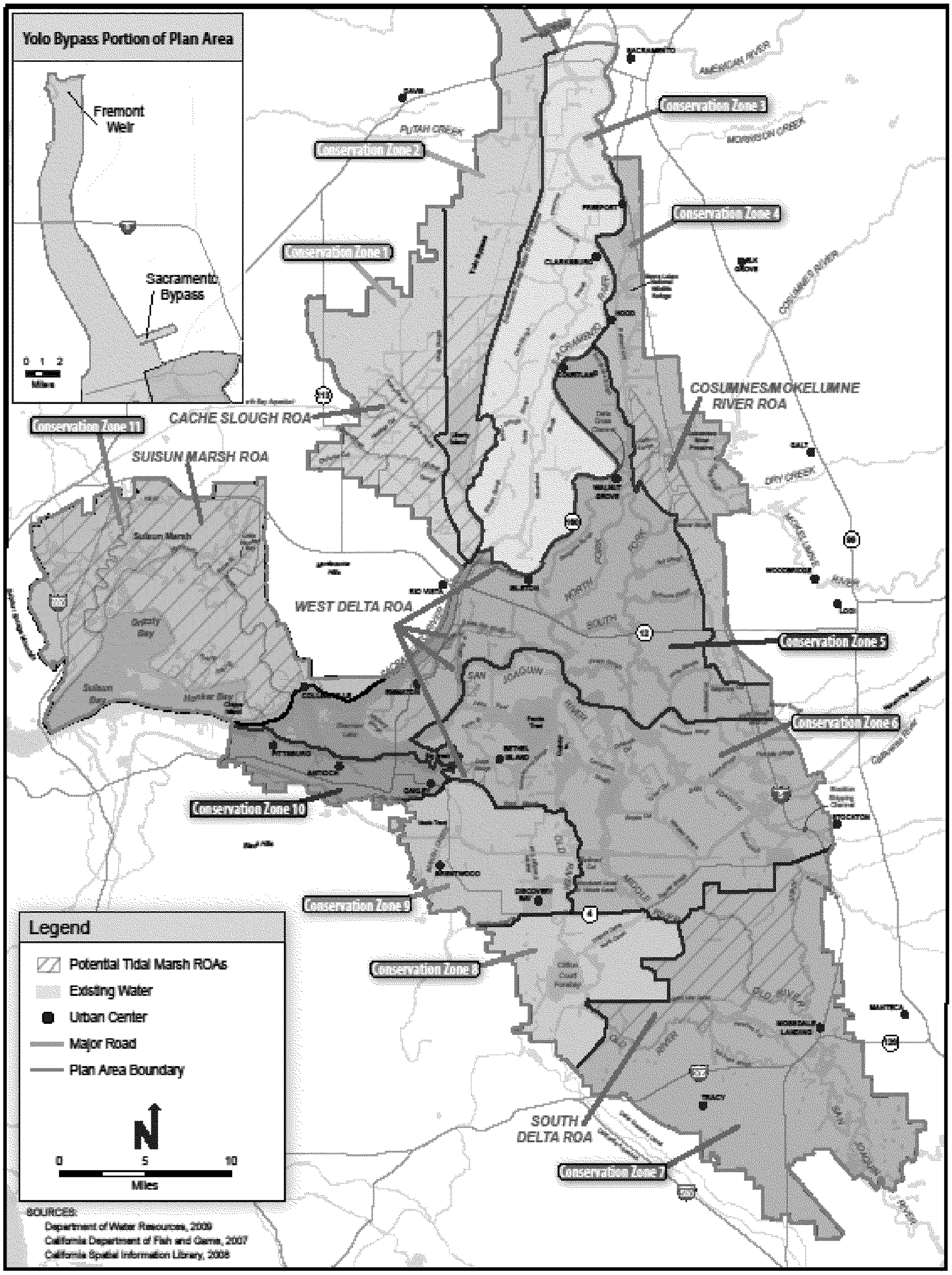


Figure A-9. Conservation Zones and Restoration Opportunity Areas (ROAs)

Table A-4. Geographic Subregions within the BDCP Study Area

Geographic Region	Subregion	Aquatic Covered Species Present
Delta	South Delta	Delta smelt, Sacramento splittail, salmonids
Delta	North Delta	All
Delta	Cache Slough	All
Delta	Yolo Bypass	Delta smelt, Sacramento splittail, salmonids, sturgeons
Delta	Western Delta	All
Delta	Suisun Marsh	All
Delta	Suisun Bay	All
Sacramento River	American River	Salmonids
Sacramento River	Sacramento 143	Salmonids, sturgeons, lamprey, splittail
Sacramento River	Feather River	Salmonids, sturgeons, lamprey
Sacramento River	Sacramento 194	Salmonids, sturgeons, lamprey
Sacramento River	Sacramento Keswick	Salmonids, sturgeons, lamprey
Sacramento River	Clear Creek	Salmonids, lamprey
San Joaquin River	Stanislaus River	Salmonids, sturgeons
San Joaquin River	Tuolumne River	Salmonids, sturgeons
San Joaquin River	Merced River	Salmonids, sturgeons
San Joaquin River	San Joaquin River	Salmonids, sturgeons

- *Ecological units*. These are localized, distinct areas within hydrodynamic subregions that have ecological significance to the species and the BDCP. Ecological units include the restoration opportunity areas (ROAs) defined in Chapter 3 as well as other areas that may be defined for analysis purposes, such as individual stream reaches like Steamboat and Sutter Sloughs in the north Delta subregion.

A.1.8 Species Models

Species models define a scientific hypothesis regarding how species perceive the environment and are thereby affected by BDCP actions (Figure A-10). They include the spatial and temporal distribution of life stages as well as the distribution of stressors on each life stage. Models for each species are described in Appendix B [Note: Ultimately, these species models may be bundled with the Conceptual Foundation and Analytical Framework as Appendix A].

Species affected by the BDCP have complex life histories developed in response to the wide array of environments and ecological challenges of the San Francisco estuary and Central Valley. The life history, habitat requirements and stressors affecting various species has been described in numerous publications, much of which is captured by the Delta conceptual models (http://www.dfg.ca.gov/ERP/conceptual_models.asp). Recent reports regarding the POD also provide useful conceptual models for those covered fish species that are resident to the Delta (Baxter et al. 2010).

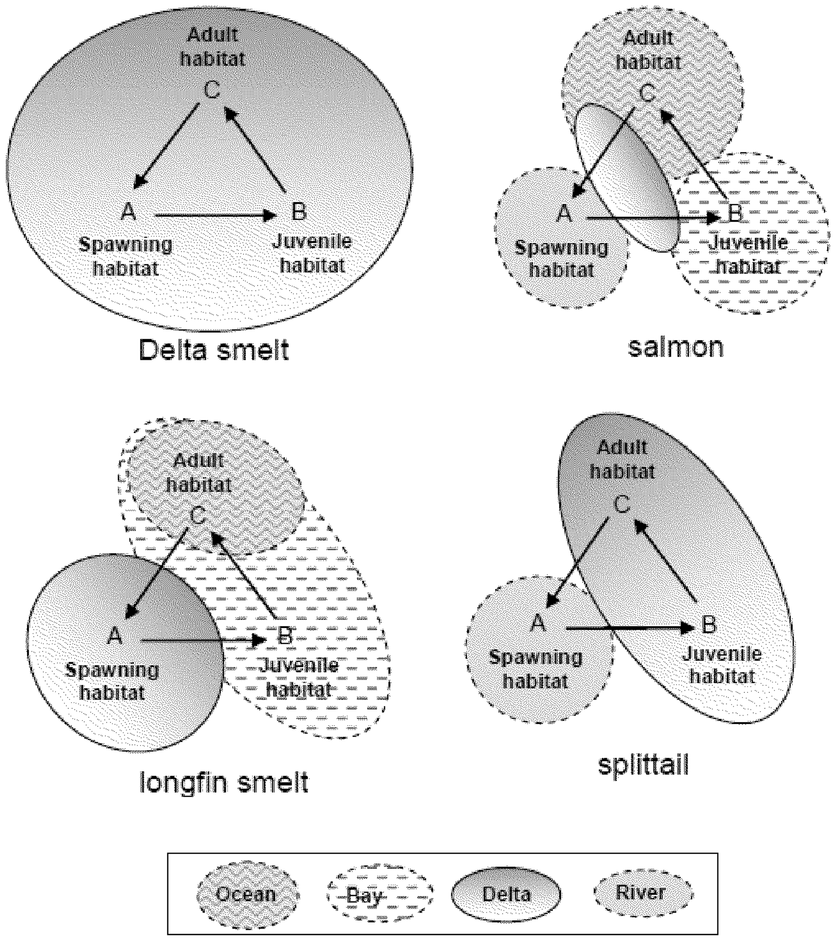
Beyond the Delta conceptual models, there are also numerous efforts to develop quantitative behavioral and population models for some of the species, specifically delta smelt and Chinook salmon. Some of these models are in their early stages of development and have not been published; others have been published and are available for use in the Effects Analysis.

Fish life histories can be broadly classified as anadromous (e.g., Chinook salmon), restricted anadromous[3] (e.g., the majority of delta smelt), and resident (e.g., a minority of delta smelt that reside in the Cache Slough subregion (Baxter et al. 2010). True anadromous behavior like that of salmon involves reproduction and early development in fresh water followed by migration to marine waters where most growth and maturation occur. Restricted anadromous behavior is used here to refer to species that spawn in freshwater areas and migrate to the low-salinity areas of the Delta to mature, and is characteristic of many estuarine species. A resident life history occurs within a single hydrologic environment (e.g., fresh water or salt water).

Because of the different types of life histories, species experience the Delta and the effects of the BDCP in unique ways. Figure A-10 shows fish life histories as triangles indicating movement of life stages across different habitat types. The path begins in the spawning habitat where adults produce offspring. The larval fish disperse to the juvenile habitat and eventually move to the adult habitat. The path is completed when the adults migrate back to the spawning habitat to reproduce. The population dynamics of a species are determined by the survival of fish over the migration path, the number of offspring produced by adults in the spawning habitat, and the number of times adults cycle between the adult and spawning habitats during their (BDCP Science Advisors 2007). Success of the species is a function of the quality and quantity of habitat available at each point in the life history triangles. In Figure A-10 it is clear that each type of life history (i.e., anadromous, restricted anadromous, or resident) experiences the Delta and the BDCP Plan Area differently. Delta smelt spend their entire life within the Plan Area; hence, the BDCP may have a greater chance at contributing to their recovery. Salmon, on the other hand, spend limited periods in the BDCP Plan Area. While conditions in the Study Area are important to salmon, their success is dependent on conditions across a much wider geography and cannot be affected by BDCP.

The complexity of Delta fish species life histories and the diversity of habitats supporting different life stages mean that their abundance and persistence over time are due to many factors (Kimmerer 2004). The population dynamics of species and their historical, current, and future abundance are the result of interplay between drivers, environmental processes, and stressors operating across multiple physical and biological scales. Hence the search for the "smoking gun" to explain the demise of species such as delta smelt leads to frustration (BDCP Science Advisors 2007). This calls for a more holistic approach to species recovery that focuses on recovery of the ecosystem and habitats.

[3] Restricted anadromous behavior is also referred to as "semi-anadromous" (e.g., Bennett 2005).



Note: Arrows indicate migration among habitat types (BDCP Science Advisors 2007)

Figure A-10. General Pattern of Use of the Delta by Covered Species over Their Life Cycle

BDCP conservation measures focus on providing benefits for species listed under the ESA and the California Endangered Species Act (CESA), as well as other special-status species. The plan identifies goals and objectives for numerous sensitive wildlife, plant, and fish species that are addressed by the conservation measures. Fish species addressed in the BDCP effects analysis (Chapter 5) are listed in Table A-5.

Table A-5. Fish Species Covered by the BDCP and Addressed in the Effects Analysis

Common Name	Scientific Name	Life History
Delta smelt	*Hypomesus transpacificus*	Restricted anadromous (some resident)
Longfin smelt	*Spirinchus thaleichthys*	Anadromous
Winter-run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous
Spring-run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous
Fall- and late fall–run Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous

Steelhead	*Oncorhynchus mykiss*	Anadromous
Green sturgeon	*Acipenser medirostris*	Anadromous
White sturgeon	*Acipenser transmontanus*	Anadromous
Sacramento splittail	*Pogonichthys macrolepidotus*	Restricted anadromous
River lamprey	*Lampetra ayresi*	Anadromous
Pacific lamprey	*Entosphenus tridentata*	Anadromous

A.1

A.2 ANALYTICAL FRAMEWORK FOR EFFECTS ANALYSIS

A.2.1 Purpose and Scope of the Analytical Framework

The Analytical Framework describes the general methodology and structure of the analysis of the effects of the BDCP on the covered aquatic species (the analysis of the effects of BDCP on terrestrial species will be described in Appendix X). The purpose of the Analytical Framework is to provide a general scheme and logic for the effects analysis. Major tools and models that are likely to be used in the analysis are discussed; additional tools and detailed methodologies will be discussed in each appendix relating to a stressor category. The intent of the Analytical Framework is to lay out a general approach and describe concerns and issues related to the analysis of the effects of BDCP actions.

The Analytical Framework reflects the concepts and structure of the Conceptual Foundation. The Conceptual Foundation includes a set of ecological principles taken from the "Principles for Conservation Planning in the Delta" developed by the BDCP Science Advisors (BDCP Science Advisors 2007). The Science Advisors included three principles that relate to the Analytical Framework:

1. Data sources, analyses, and models should be documented and transparent so they can be understood and repeated. The BDCP analysis will use generally recognized and well documented analytical tools. All models have strengths and limitations and are appropriate only for a limited set of applications.
2. Ecosystem responses, especially to changes in system configuration, can be predicted using a combination of statistical and process models. Statistical models document status, trends, and relationships between responses and environmental variables, whereas process-based models are useful in understanding system responses and for forecasting responses to new conditions.
3. There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change. Uncertainty is inherent in the behavior of complex ecological systems. Some of the uncertainty is reducible through research but some is characteristic of ecological systems (BDCP Science Advisors 2007).

A.2.2 Structure of the Effects Analysis

A.2.2.1 *Conceptual Structure*

The structure of the Analytical Framework draws from the Conceptual Foundation (Figure A-11 and Figure A-12). Environmental conditions are described by a set of species-neutral Environmental Attributes such as temperature, turbidity and salinity. The environmental condition is viewed or perceived by each species and life stage in unique ways to produce a species response, termed the biological condition, at a life stage and population level. Drivers constrain overall system performance and set normative functions of the system. Actions may modify the Environmental Attributes and be characterized as stressors or enhancers of habitat suitability. Most stressors and enhancers have both an environmental impact and a biological response. In other words, an action such as restoration of tidal wetlands changes the environment and produces a biological response in a covered species.

A.2.2.2 *Geographic Structure*

Elements of the BDCP effects analysis are organized using the geographic structure described in the Conceptual Foundation (Figure A-11). Drivers and conservation measures act across a range of geographic and biological scales. Regional geology and climate are large-scale drivers whereas local geology and microclimates can drive conditions at smaller scales.

The BDCP effects analysis will be organized using the scheme outlined in the Conceptual Foundation:

a. Plan Area

b. Geographic Regions (e.g., the Delta, Sacramento River, San Joaquin River)

c. Geographic Subregions (e.g., North Delta, South Delta)

d. Ecological Units (e.g., Restoration Opportunity Areas [ROAs])

Much of the analysis will be focused at the geographic sub-regional level while recognizing larger-scale constraints and smaller-scale components. Ecological units will be defined as necessary for analysis (e.g., a particular ROA).

A.2.2.3 *Temporal Structure*

The BDCP is intended to address habitat restoration for covered species and statewide water supply over a 50-year period. As will be discussed below, the analysis will address conditions at multiple points within this period, reflecting the implementation schedule for conservation measures. Much of the analysis of conditions in the Delta is based on CALSIM II projections of flow under current conditions and under BDCP conservation measures. CALSIM II uses a monthly time step and, as a result, much of the analysis of flow-related attributes is also at a monthly time scale. Some models such as DSM2 begin with the CALSIM II monthly output to derive finer-scale results for some parameters.

A.2.2.4 *Regulatory Structure*

The analytical design of the effects analysis supports evaluation of the BDCP conservation measures with regard to State and Federal regulatory criteria. The analysis is designed to address the requirements of Sections 7 and 10 of the ESA and California Natural Community Conservation Planning Act (NCCPA). Section 10 of the ESA requires that HCPs identify the impacts likely to result from the proposed taking of species covered by the plan. To issue permits, the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service

(NMFS) must find that the BDCP conservation strategy minimizes and mitigates the impacts of this taking to the maximum extent practicable for each of the covered species. The effects analysis will characterize the adverse, beneficial, and net impacts of the covered activities on each of the covered species to support that determination.

Under the Section 7 formal consultation process, the Federal action agency prepares a BA (BA) that includes an evaluation of the potential effects of the proposed Federal action on listed and proposed species and designated and proposed critical habitat. On the basis of the BA and on other information, USFWS and NMFS prepare biological opinions (BOs) to determine whether the proposed Federal action is likely to jeopardize listed species or result in the adverse modification or destruction of critical habitat. The BDCP is intended to serve as the BA for four Section 7 consultations: intra-agency consultations with USFWS and NMFS (for the issuance of the permits), and a consultation between the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) and USFWS and NMFS for continued operation of the CVP. To support these consultations, the BDCP effects analysis will evaluate all direct, indirect, and cumulative effects on the covered species and effects on designated and proposed critical habitat.

The BDCP effects analysis also will provide the basis for the California Department of Fish and Game (DFG) to make their findings under the NCCPA. The analysis supporting NCCPA will address whether the plan conserves the covered species; maintains ecological integrity of habitat, ecosystem functions, and biological diversity; establishes linkages to habitat areas outside the plan area; protects and maintain habitat areas of sufficient size to support sustainable populations of covered species; incorporates a range of environmental gradients and habitat diversity; and sustains movement and interchange of organisms to maintain the integrity of habitat areas within the Plan Area.

A.2.3 Models Used in BDCP Analysis

Assessment of the impacts of stressors resulting from the BDCP will involve a combination of quantitative, qualitative, and statistical models. A model is a logical organization of data and observations leading to a conclusion about how a system functions or performs. Quantitative models predict a numeric outcome of an action based on the manipulation of data by mathematical algorithms. The algorithms in a quantitative model reflect a conceptual model of the relationship between attributes, processes, and outcomes. Development of quantitative models requires that sufficient theory and data are available to construct algorithms and to explicitly describe the relationship between system attributes. Qualitative models, including conceptual models, describe a logical relationship between variables and summarize scientific investigations. Conceptual models are the first step in constructing quantitative models but they can also stand alone as a working hypothesis of the phenomenon.

The BDCP Science Advisors distinguished two categories of quantitative models, process and statistical, for use in the BDCP analysis (Principle 2 above, BDCP Science Advisors 2007). Statistical models are based on correlations and regressions between different attributes to describe change over time. These models do not necessarily provide mechanistic explanations for phenomena but instead create probabilistic statements of relationships between variables. Though causal relationships between independent and dependent variables are not necessary for a statistical model, a common presumption is that the relationship is meaningful (i.e., not spurious) and usable as a tool to predict a future condition.

Process models as defined by the BDCP Science Advisors describe hypotheses about causal relationships. Process models are often biologically, spatially, or temporally complex relationships and are built on statistical and conceptual models. A life history model for a species is an example of a process model in which relationships between life stages and environmental factors are integrated across a species' life history to investigate population-level responses to environmental conditions. Hilborn and Mangel (1997) called these *scientific models* and discussed their application as tools to understand how nature might work and create predictions of future conditions given that the system works as described. CALSIM II is perhaps an example of a scientific model because it is based on well-established hydrologic theory and a record of extensive observation that result in an explicit description of water movement through the Delta.

Data and theory are limited, however, for many processes that influence BDCP covered species. In these cases qualitative conclusions are appropriate where the general body of scientific literature can be used to form best professional judgment and conceptual models. Qualitative assessments involve the synthesis of general and specific scientific theory and information. Ideally, an explicit conceptual model is used to organize information and explain conclusions based on logic, professional judgment, and peer review. DRERIP[4] is a set of conceptual models for key species and processes in the Delta. That process currently is revising conceptual models for several Delta species and processes that contribute the BDCP species models.

In the BDCP effects analysis, all of these types of models will be used to inform conclusions regarding the effects of the covered activities. Results across a suite of analyses will be synthesized (i.e., "rolled-up") to create overall conclusions regarding biological conditions at a population and, in some cases, a species level. The integration of multiple lines and types of evidence to determine ecological risk often calls for a weight-of-evidence approach (Suter 1993). This approach weighs different lines of evidence, examines convergence of conclusions, and evaluates diverging information to create a structured approach to integrating multiple lines of evidence (Weed 2005). Weight-of-evidence analysis provides a useful approach for reaching conclusions regarding BDCP impacts where multiple analyses and factors are present.

The BDCP Analytical Framework includes a number of models addressing the environment, stressors, and covered species (Figure A-11). Each group of models includes quantitative, qualitative, and statistical models.

[4] (http://www.dfg.ca.gov/ERP/conceptual_models.asp)

A.2.3.1 Environmental Models

Environmental models set the stage for the analysis by describing key physical and chemical conditions across the Study Area. This includes assessment of flow, temperature, salinity and turbidity that are addressed by models such as CALSIM II and DSM2. These models are the basis for many other models used in the BDCP effects analysis. In addition to the well-recognized quantitative models such as CALSIM II, conclusions and conceptual models based on best professional judgment are used to describe conditions and synthesize information at this level. Note that environmental models also can be conservation measure models when they directly assess BDCP actions.

A.2.3.2 Conservation Measure Models

Conservation measure models evaluate the impact of BDCP covered activities such as habitat restoration, improved water quality, or a change in water export operations (Figure A-11). Analysis of conservation measures address stressors as negative changes to the biological condition as well as enhancers as positive changes in the biological condition. Conservation measure models link attributes affected by the activity to species and life stage. BDCP covered activities include conservation measures described in Chapter 3 as well as indirect effects of BDCP actions. Models addressing specific conservation measures are described in the appendices.

A.2.3.3 Species Models

Species models summarize and organize the information relevant to the performance of species and life stages in the Delta (Figure A-11). Species models can include life stages, spatial and temporal distribution, life history, physiological needs, and key habitats. Species models provide a quantitative or qualitative conclusion on species or life stage performance measured as survival (productivity), abundance, or biological diversity. The multistage life cycle model for delta smelt of Maunder and Deriso (2011) is an example of a quantitative species model. The DRERIP species models such as the one developed for delta smelt by Nobriga and Herbold (2009) are examples of conceptual species models. Additional conceptual models for covered species appear in Appendix X.

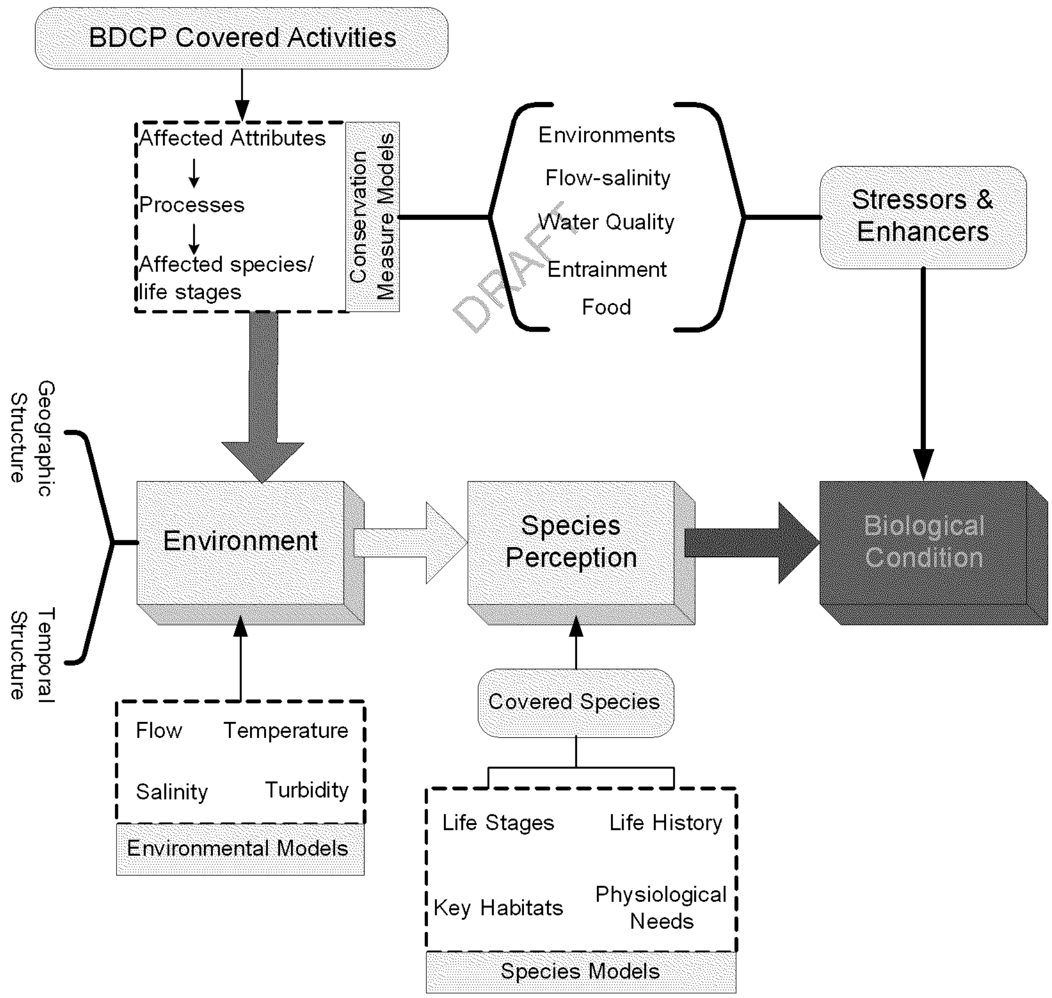


Figure A-11. Generalized Flow of Information in the BDCP Biological Effects Analysis

A.2.4 BDCP Analytical Structure

Evaluation of BDCP impacts will be made by comparing biological performance of covered species with environmental conditions expected under BDCP conservation measures at future implementation periods (Section A.X.X.X) to baseline environmental conditions. Regulatory structure in the base case scenarios reflects regulations in place in 2011 including especially the 2008 USFWS BO for delta smelt and the 2009 NMFS BO for salmonids and green sturgeon.

A.2.4.1 *BDCP Analytical Scenarios*

Base case and conservation measure scenarios characterize an assumed set of conditions for evaluation purposes. However, it is important to appreciate that conditions within and across years are highly variable. Conditions and regulatory responses in any particular year in the past or future may vary from the assumed conditions in the analytical scenarios. Environmental conditions change in response to variation in precipitation, temperature, and ongoing habitat restoration and other actions designed to benefit covered fish species. Regulation of flow, exports and other conditions can be described generally in the scenarios, but in reality, regulators exercise considerable in-season ability to meet environmental and management standards. Species abundance varies widely between years in response to factors affecting species across their life histories.

A.2.4.1.1 Conservation Measure Scenarios

BDCP proposes 19 conservation measures that address a spectrum of aquatic and terrestrial environmental conditions across the Study Area. This includes 10 conservation measures directed at restoration of 113,000 acres of aquatic and terrestrial habitat, a single conservation measure describing the dual conveyance structure and other flow-related actions, and eight measures dealing with water quality, predator control, and other factors. DWR is currently screening and evaluating a set of alternative facilities and locations for the dual conveyance structure and alternative strategies for habitat restoration. A subset of these alternatives will be evaluated in the EIR/EIS for BDCP.

The 19 conservation measures constituting the BDCP conservation strategy will be evaluated separately and in combination. Proposed project (PP) analytical scenarios will evaluate the conservation measures in the context of baseline conditions. In addition to the conservation measures, each PP scenario will incorporate expected changes to regional climate for each implementation period as described in Section A2.4.4. The evaluations will consider environmental conditions and expected biological performance (e.g., abundance, productivity, capacity) of the covered species in relation to the baseline and the implementation of the BDCP conservation strategy to evaluate the biological benefits of the conservation measure.

A.2.4.1.2 Environmental Baseline Scenarios

The environmental effects analysis begins with a definition of the environmental baseline. Baseline conditions reflect requirements of the California Environmental Quality Act (CEQA), National Environmental Policy Act (NEPA) and the Federal ESA. There are some differences in the requirements of each law regarding the definition of baseline conditions. However, all of these laws require a description of existing environmental conditions to inform and develop the environmental baseline. Differences between the legal requirements mean that the BDCP analysis uses multiple baseline conditions.

The BDCP baseline condition reflects environmental conditions that exist in the Study Area prior to project approval. This includes the current extent of species habitats, existing water quality and pollutant inputs, and existing water temperatures. The BDCP baseline also will reflect the ecological effect of the 2008 and 2009 Operating Criteria and Plan (OCAP) BOs developed by the USFWS for delta smelt and NMFS for salmonids and green sturgeon. These actions were added to the regional operations structure previously proscribed under D1641 provisions of the State Water Resources Control Board.

In CEQA, the environmental setting is defined as the physical conditions that exist at the time the notice of preparation is published or at the time the environmental analysis commences. The requirements for the environmental baseline under ESA Section 7 differ from those in CEQA. The ESA baseline includes the impacts of all past and present Federal, State and private actions and the anticipated impacts of all proposed Federal projects that have undergone Section 7 consultations. Under NEPA, the baseline reflects existing environmental conditions including the effects of past and ongoing actions. Because of these different regulatory provisions, the BDCP effects analysis will include two baseline conditions. These two baselines are defined in Table A-6 and differ in regard to the inclusion of conditions related to the fall X2 location.

Table A-6. Description of Environmental Baseline Conditions for Evaluation of BDCP Alternatives

Baseline Scenario	*Regulatory Basis*	*Description*
EBC1	CEQA	2008 USFWS BO and 2009 NMFS BO, but without Fall X2
EBC2	ESA Section 7	2008 USFWS BO and 2009 NMFS BO

A.2.4.2 *Implementation Periods*

The 19 BDCP conservation measures will be implemented over a 50-year period. Measures will begin at different points over that period reflecting the implementation schedule in Chapter 6 (Figures 6-1 and 6-2). In addition, over this implementation period, climate across the Study Area is expected to change at local, regional, and larger scales (Hayhoe et al. 2004). To account for the implementation schedule and climate change, evaluations of BDCP conservation measures will be made using conditions expected during four periods within the HCP period. Analytical comparisons will use all or a subset of these periods as appropriate.

1. **Current.** The two base conditions, EBC1 and EBC2, describe conditions in the Delta with respect to the BO provisions under habitat and climate conditions present at the commencement of implementation of BDCP.
2. **Near-Term (NT).** Near-term refers to conditions expected under BDCP in the first 10 years following implementation of the program. During this period, BDCP is expected to address a substantial portion of the planned aquatic and terrestrial restoration with associated improvements in water quality and food production. Benefits will not be immediate but will accumulate as a result of time required for land acquisition and for maturation of habitat restoration actions. During this period, the dual conveyance structure will be constructed but no new hydrologic operations will occur. Climate conditions in the near-term reflect physical analysis of the 2015 conditions.
3. **Early Long-Term (ELT).** This evaluation period is from 10 years after BDCP permits are issued through 15 years from BDCP authorization. During this period, significant changes will occur to the Delta environment as a result of BDCP. Operation of the dual conveyance structure is expected during this period while changes to tidal, floodplain,

and terrestrial environments should occur. Climate conditions in the early long-term reflect physical analysis of the 2025 conditions.

4. **Late Long-Term (LLT).** The Late Long-term period reflects the full implementation and maturation of BDCP actions from year 15-50. During this period, all planned habitat restoration should have occurred along with full application of dual conveyance and other measures. Climate conditions in the late long-term reflect physical analysis of the 2060 conditions.

A.2.4.3 *Water Years*

Inflow to the Delta from the Sacramento and San Joaquin Rivers is highly variable, reflecting annual variation in precipitation, regional climate trends, and hydrologic operations. As discussed above, water management changes between years to accommodate a variety of water needs. To reflect the range of flows expected over the BDCP implementation period, the analysis will use flow conditions over the 82-year CALSIM II base period averaged to reflect five water year types. These water year types have been established by the California Department of Resources for hydrologic analysis (California Department of Water Resources 2009). For those actions that are affected by flow a range of water year conditions will be used to capture the array of impacts across water conditions. The analysis will evaluate the change in biological condition resulting from BDCP actions for each of the following water year types:

1. Critical (12 years)
2. Dry (18 years)
3. Below Normal (14 years)
4. Above Normal (12 years)
5. Wet (26 years)

A.2.4.4 *Climate Change*

Over the course of the BDCP implementation period, regional climate is expected to change in California (Hayhoe et al. 2004; Cayan et al. 2009). It is assumed that these changes will occur independently of BDCP and that BDCP conservation measures have no direct impact on climate change or on regional adaptation to climate change. However, it is likely that expected climate change will affect the biological impacts of BDCP, and for this reason, projected climate change is incorporated into the proposed project for the implementation periods described in Section A.X.X.X.

Early long-term conditions for the PP scenarios incorporate expected climate change by 2025, while the late long-term scenarios incorporate climate change conditions expected in 2060. Climate change is expected to increase temperature and raise sea levels in the BDCP Study Area (Table A-7). Precipitation change is more variable across the region and difficult to predict. However, most projections point to an increase in precipitation in the northern Sacramento basin and a decrease in precipitation in the southern San Joaquin basin. Although not modeled, an important change is the expected increase in tidal amplitude.

Table A-7. Climate Change Assumptions Built Into BDCP CALSIM II Analysis

Parameter	*Change relative to 1971–2000*	
	Early long-term (ELT)-2025	*Late long-term (LLT)-2060*
Temperature	+.7-1.4 Co	+ 1.6-2.7 Co
Precipitation		
Sea Level	15 cm (6 inches)	+ 45 cm (18 inches)

A.2.5 Analysis by Conservation Measure

Specific analyses used to assess the impacts of BDCP conservation measures will be discussed in detail in the appropriate appendix. The sections below summarize the issues and general analytical approach that will be described in detail in each appendix.

A.2.5.1 *Habitat*

Habitat refers to the collection of environments and attributes needed for life stages of a species to survive and move to the next life stage. To be successful, a species requires necessary habitat across its life history pathways to allow it to complete its life history. Most of the covered species require a diversity of habitat types over the course of their life histories with different life stages requiring distinctly different habitat conditions. The abundance and resiliency of a population depends on the quality and quantity of all habitat needed to complete all life stages. Hence, species performance, measured as abundance, productivity, or persistence over time, is a function of the physiological needs of the species acting against the template of the environment (Figure A-12). The focus of this section is habitat <u>quantity</u> and BDCP actions that increase or decrease extent (e.g., acres or volume) of aquatic environments defined as key habitat for different species. Aspects of habitat <u>quality</u> attributes such as flow, nutrients, salinity, turbidity, pollutants, temperature, entrainment, food supply, and other factors will be considered under other conservation measures.

A.2.5.1.1 The Issue

Habitat conditions in the Delta have been altered greatly by numerous human actions beginning in the nineteenth century. Diking and draining of coastal areas has eliminated about 95% of the tidal wetlands in the estuary (Kimmerer 2004). Much of the nearshore area around the Delta has been converted to agricultural or urban environments. Tidal wetlands and adjacent uplands form key habitat for many of the covered species such as delta smelt and splittail and a variety of native plants, birds, mammals, reptiles, and amphibians.

Other habitats for the covered species have been affected by human activities in more subtle ways. All Delta fish species have salinity tolerances and preferences based on physiology, food availability, and other factors. Some species may concentrate around and upstream of the LSZ defined by the position of X2. The LSZ moves in response to inflow, thereby affecting the quantity of low salinity habitat (Kimmerer 2004). Water management activities have altered the historic flow patterns and changed the amount of low salinity habitat. The effect of the quantity of low salinity habitat on delta smelt and other species is not clear and the subject of varying hypotheses (Kimmerer et al. 2009; Baxter et al. 2010). While the quantity of low salinity habitat may be important for some species, other issues such as turbidity, food, predators, and temperature may be of equal or greater importance in determining the abundance of delta smelt.

A.2.5.1.2 Covered Activities

BDCP includes 10 conservation measures directed at protecting and restoring up to 113,000 acres of aquatic and terrestrial habitat. This includes 65,000 acres of tidal wetlands and 10,000 acres of floodplain. This represents a doubling of the available tidal wetland habitat in the Delta. Conservation Measure 1 includes water facilities and operations that alter inflow to the Delta and affect the quantity of low-salinity habitat.

A.2.5.1.3 Analytical Approach

Analysis of habitat changes under BDCP begins with the species models developed in Appendix X. These models identify key habitats for the species and their life histories. For example, tidal wetlands are key habitat for delta smelt spawning. BDCP will restore substantial areas of nearshore, floodplain, and river margin habitat. To evaluate the benefits of these habitat restoration measures Habitat Suitability Index (HSI) models will be developed for aquatic covered species. HSI models provide a transparent and objective approach to quantifying the value of an area for a particular species (U.S. Fish and Wildlife Service 1981). Functions will be developed for key habitat attributes using a score of 0-1 with a 1 designating key habitat for the species life stage with a declining habitat preference for other environments and a 0 indicating no use of the environment by the species life stage. Functions and rankings will be based on existing HSI models when available, existing literature, and professional judgment. For example, HSI models are available for splittail (Sommer et al. 2008) and white sturgeon (Gard 1996). A Geographic Information System (GIS) will be used to map the extent of key habitats for covered species in the baseline and proposed project implementation periods. Once key habitats needs are identified and habitat types are mapped and quantified, associations and evaluations can be made for each species to develop the HSI models. The habitat benefits to each species will be compared before and after BDCP habitat restoration actions.

The evaluation of restored habitat under BDCP will be based on a weighted habitat area approach incorporating the HSI results. This will involve three steps: (1) determination of habitat preferences for each species, (2) mapping of habitat types in the baseline and with BDCP at each implementation period, and (3) comparing the weighted area of the restored habitats in the baseline and with BDCP. Determination of habitat preferences by life stage will be based on published literature, the conceptual models developed in DRERIP, and consultation with species experts. The hypothetical footprint of tidal and floodplain habitat restoration described in Chapter 5 will be used to determine habitat benefits using the HSI models and the weighted habitat area approach described above. Habitat restoration will reflect expansive breaching of levees where possible; habitats are not independent and restoration of one type of habitat (e.g., intertidal wetlands) may affect the quantity of other habitat types such as low salinity areas.

The final step is to compute a weighted habitat area based on the key habitat rating. For example, 5,000 acres of a habitat type with a key habitat rating for a species life stage of 1.0 would provide 5,000 weighted acres of habitat for the life stage. The same amount of habitat with a rating of 0.50 for the species life stage would provide only 2,500 weighted acres of habitat. The amount of weighted habitat can be summed across habitats to provide an estimate of the weighted total habitat for the species in a scenario.

A.2.5.2 *Flow-Salinity*

Flow and salinity define many of the environmental qualities of estuaries including the Bay-Delta (Kimmerer 2004). Flow by itself has limited physiological impact on fish though it is an important behavioral cue for many species (e.g., delta smelt, Sommer et al. 2011). However, flow governs the condition of many other attributes of biological interest. For example, flow determines the movement and dilution of water quality constituents, salinity, the amount and pattern of habitat available for some species, turbidity, movement of food, and distribution of aquatic species. Because of its overarching impact on many biologically important attributes, the analysis and modeling of flow are often the first step in the study and analysis aquatic habitats.

Salinity is a physiological attribute and species have distinct salinity tolerances. However, the impact of salinity on species distribution is more complex than would be indicated by laboratory-based salinity tolerances. Salinity patterns in the estuary can set up density gradients like the LSZ (defined by the location of X2) that concentrate species like delta smelt that can tolerate much higher salinity. The concentration of species alters the aquatic biological community, affecting the mix of species at all trophic levels with different salinity tolerances.

A.2.5.2.1 The Issue

Estuarine environments are affected by the annual flow, seasonal and daily distribution of flow. Flow in the Delta is a function of precipitation and water management including export of water from the Delta. Development of the Delta water supply system has altered the flow patterns relative to the normative condition with impacts on ancillary conditions affected by flow including the distribution of salinity (Kimmerer 2004).

A.2.5.2.2 Covered Activities

Analysis of current and future flow conditions is important to the analysis of other flow-related conditions such as salinity, turbidity, water quality, and habitats. In addition, operation of the dual conveyance structure included in BDCP Conservation Measure 1 will alter the outflow from the Sacramento and San Joaquin Rivers.

A.2.5.2.3 Analytical Approach

Flow and salinity conditions are the result of relatively well defined physical principles and, for this reason, useful quantitative models exist to capture conditions in the baseline and estimate conditions in the future. Although based on established principles, the models are quite complex reflecting the intricacies of delta flow patterns and project operations. Because flow primarily affects other attributes of biological significance, biological impacts are evaluated through techniques discussed under other conservation measures.

The general analytical design for analysis of flow impacts is shown in Figure A-12. Flow under the base conditions, EBC1 and EBC2, is compared to flow under the proposed project (PP) at two points in time across five water year conditions. As explained above, the two base conditions, EBC1 and EBC2, differ in that EBC1 removes the fall X2 provisions of the 2008, 2009 BOs, whereas EBC2 contains all provisions of the BOs. The existing biological conditions are compared to the proposed project at two points in time: early long-term (ELT) and late long-term (LLT) as described in Section A.X.X.X. Because flow and salinity conditions are not expected to change until the dual-conveyance structure is completed in the early long-term, baseline flow is not compared for the near-term period.

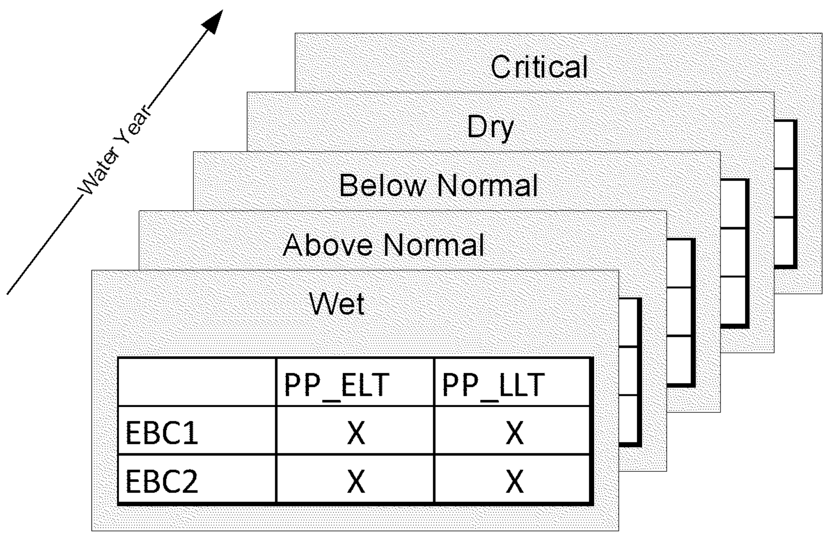


Figure A-12. Generalized Analytical Design of BDCP Flow Analysis

Analysis of flow conditions in the analytical design in Figure A-12 will rely primarily on two models, CALSIM II and DSM2 (Figure A-13). CALSIM II[5], developed by the California Department of Water Resources and the U.S. Department of the Interior, Bureau of Reclamation, is a comprehensive model of the hydrology of Delta and SWP and CVP operations. Sacramento

[5] <http://modeling.water.ca.gov/hydro/model/index.html>.

Valley and tributary hydrology inputs are developed by adjusting the historical sequence of monthly stream flows over an 82-year period (1922 to 2003) to represent predicted flows at future scenario within each tributary watershed. The resulting hydrology represents the water supply available from Central Valley streams to the CVP and SWP under the future scenario. CALSIM II is the primary method for analyzing flow impacts of BDCP Conservation Measure 1. In addition, monthly estimates of flow from CALSIM II are the basis for other models such as DSM2 that analyze flow-related conditions in the Study Area related to other conservation measures.

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento–San Joaquin River Delta. DSM2 is bounded by the monthly flow estimates from CALSIM II (Figure A-13). The model is developed and maintained by the California Department of Water Resources to provide dynamic simulation of hydrological characteristics of the Delta. DSM2 consists of three modules:

- DSM HYDRO simulates one-dimensional hydrodynamics including flows, velocities, depth, and water surface elevations. HYDRO provides the flow input for other modules.
- DSM QUAL simulates one-dimensional fate and transport of water quality constituents such as temperature and dissolved oxygen given a flow field simulated by HYDRO.
- DSM PTM simulates pseudo 3-D transport of neutrally buoyant particles based on the flow field simulated by HYDRO.

The array of outputs and the daily (or less) time step of DSM2 make it particularly applicable to the analysis of biological impacts of conservation measures. DSM2 output is, however, limited to the Delta; analysis of conditions in the tributaries relies on coarser data from CALSIM II.

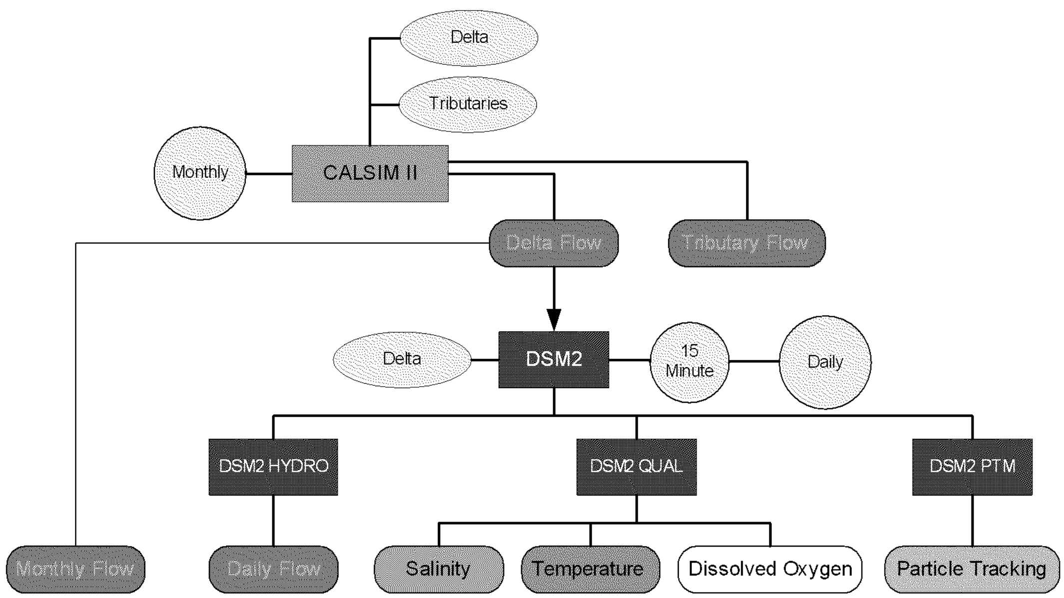


Figure A-13. Relationship between CALSIM II and DSM2 Models and Derivation of Environmental Conditions in BDCP

A.2.5.3 *Turbidity and Water Quality*

A.2.5.3.1 The Issue

High turbidity is the normative condition for the Bay-Delta (Kimmerer 2004). Native species have evolved strategies and life histories that accommodate and take advantage of the turbid conditions. Delta smelt in particular appear to benefit from highly turbid water; foraging success and protection from predators are mechanisms that have been suggested for the association of delta smelt with turbid conditions (Bennett 2005). However, turbidity in the Bay-Delta appears to be declining (Kimmerer 2004). This is the result of dams that block sediment flow through the Sacramento and San Joaquin systems (Wright and Schoellhamer 2004) as well as the removal of tidal wetlands that contribute particulate organic matter. Phytoplankton that contribute to turbidity and food have declined as well because of the effect of introduced Corbula clams and lowered water quality (Glibert 2010). submerged aquatic vegetation (SAV) may remove suspended sediment and increase water clarity (Baxter et al. 2010).

Water quality in the Delta has declined because of inputs from urban, industrial, and agricultural sources (Thompson et al. 2000). Ammonia levels in the lower Sacramento River and other water quality factors appear to be related to declines in phytoplankton and the pelagic fish species in the Delta (Glibert 2010).

A.2.5.3.2 Covered Activities

BDCP conservation measures have limited direct effect on water quality because most of the causes of declining water quality are outside the domain of BDCP. Conservation Measure 12 contains actions to minimize the methylation of mercury that may occur in restored wetlands. BDCP indirectly may increase turbidity and improve water quality. Turbidity may increase because of an influx of organic debris from restored tidal wetlands. Restoration such as the flooding of Liberty Island has indicated that restored wetland can increase turbidity at least at local levels. Water quality should improve as a result of converting agricultural lands that presently receive fertilizers and pesticides to tidal wetlands. High levels of ammonia in the lower Sacramento River originating from the City of Sacramento water treatment facility have been linked to foodweb changes and species declines in the Delta (Glibert 2010).

A.2.5.3.3 Approach

Existing scientific knowledge is not sufficient to make quantitative assessments of turbidity and most water quality parameters. Attempts have been made to develop models to predict water quality parameters such as selenium inputs from irrigated lands in the San Joaquin Valley. Currently available water quality models are not fully developed and are not used in BDCP analysis. Best professional judgment will be used to discuss and synthesize information related to BDCP impacts on these parameters.

A.2.5.4 Entrainment

Entrainment occurs when fish, phytoplankton, or zooplankton are pulled into water diversions. Fish are impinged on screens and removed from the system.

A.2.5.4.1 The Issue

Water diversions in the Study Area export water from the Delta and entrain covered fish species as well as phytoplankton and zooplankton. Currently there are no quantitative estimates or analysis of entrainment of phytoplankton and zooplankton (or any species other than those listed under ESA). This issue will be addressed through qualitative discussion of issues and potential problems. In the Bay-Delta, there are many water diversions with varying potential to cause entrainment, including:

- SWP and CVP south Delta pumps (South Delta Subregion).
- SWP North Bay Aqueduct Barker Slough Pumping Plant (Cache Slough Subregion).
- Mirant Delta Contra Costa Power Plant (CCPP) and Pittsburg Power Plant (West Delta Subregion).
- Other larger diversions (e.g., Freeport Regional Water Authority intake, Contra Costa Water District intakes at Rock Slough, Old River, and other locations).
- Agricultural[6] diversions and other diversions (all subregions).

Fish drawn into pumps like those in the SWP and CVP are impinged on screens or exported from the system either through the conveyance structures or salvage efforts. While juvenile salmonids and other species may survive to benefit from salvage efforts, more delicate species like delta smelt and life stages generally are assumed to be killed once they are drawn into the facilities (Miller 2011). Smaller agricultural diversions also may entrap and kill fish and other species, especially diversions that are unscreened. Power plant cooling systems also withdraw water from the Delta and can entrain fish as well.

There are two issues associated with analysis of entrainment: (1) the number of fish of different life stages that are entrained and the relationship of entrainment to facilities operation, and (2) the significance of entrainment to the status and recovery of covered species. This section will discuss only the first issue of evaluating the number of covered species entrained under BDCP conservation measures. The significance of entrainment, or any other stressor, on species performance at a population level is addressed under fish population analysis. The issues of entrainment are particularly relevant because of the impacts of entrainment on regional water management (Miller 2011). Because of the volume of water exported from these facilities and the evidence that covered species are entrained at these facilities (Brown et al. 1996), their operation has become an important focus of species recovery efforts (U.S. Fish and Wildlife Service 2008) and considerable research and analysis (e.g., Kimmerer 2011; Miller 2011).

[6] The term *agricultural diversions* includes many diversions that are not part of the SWP and CVP.

A.2.5.4.2 Covered Activities

Conservation Measure 1 calls for the construction and operation of a dual conveyance structure providing water withdrawal opportunities from the Sacramento River as well as the south Delta where the SWP and CVP facilities are located. By providing an alternative input location for CVP and SWP exports, pumping, and therefore entrainment, should be reduced at the south Delta facilities. The new north Delta intakes will be screened to minimize entrainment and are located upstream of the major distribution of estuarine species like delta smelt.

Restoration of tidal wetlands and other aquatic habitats called for in Conservation Measures 2–11 may reduce the irrigation that currently occurs on these lands through screened and unscreened diversions.

A.2.5.4.3 Approach

[Note to reviewers: there are still many issues to be worked out to develop an integrated analytical approach to entrainment. The discussion below outlines some of the most obvious components of entrainment analysis but should not be considered complete at this time.]

There are a number of analyses and models that have been used to evaluate entrainment of covered species in the Delta, especially at the SWP and CVP facilities. Each technique takes a slightly different approach using different data sets and mathematical procedures to evaluate relationships. As a result, the models do not all agree or yield unequivocal results. Risk assessment under these types of circumstances often relies on weight-of-evidence approaches to arrive at a considered conclusion based on the available information (Weed 2005). A weight-of-evidence approach is a useful route to explore as a means to form a conclusion regarding the effects of entrainment. Under this approach, the question is, "Do the various analyses point to the same conclusion regarding direction of change?" In other words, "Do the available analyses all conclude that entrainment increases, decreases, or remains unchanged under BDCP?" If the analyses point to fundamentally different conclusions (i.e., differences of direction not magnitude), can we isolate the differences to key assumptions that can be addressed through adaptive management or focused research?

Analytical methods for evaluating entrainment are specific to the entrainment facility. Entrainment analysis for a facility shares many commonalities among species, but most methods target a specific species. The following is an outline of planned entrainment analysis by species and life stage.

South Delta Pumps

The south Delta pumps are presently the greatest points of water export from the Delta and hence are believed to have the greatest entrainment of covered species (U.S. Fish and Wildlife Service 2008). Almost all analysis of entrainment in the Delta has focused on the effects of the SWP and CVP facilities on Delta fish species.

DELTA SMELT

Methods for the analysis of delta smelt entrainment are listed in Table A-8 and discussed in some detail in Appendix XX. A general scheme for analysis of delta smelt entrainment at the South Delta pumps is outlined in Figure A-14. Most of the analytical methods are linked to CALSIM II estimates of monthly flow.

Eggs

The eggs of delta smelt are adhesive and attach to substrates until they hatch (Bennett 2005). Using best professional judgment, it is assumed eggs are subject to entrainment in the south Delta pumps.

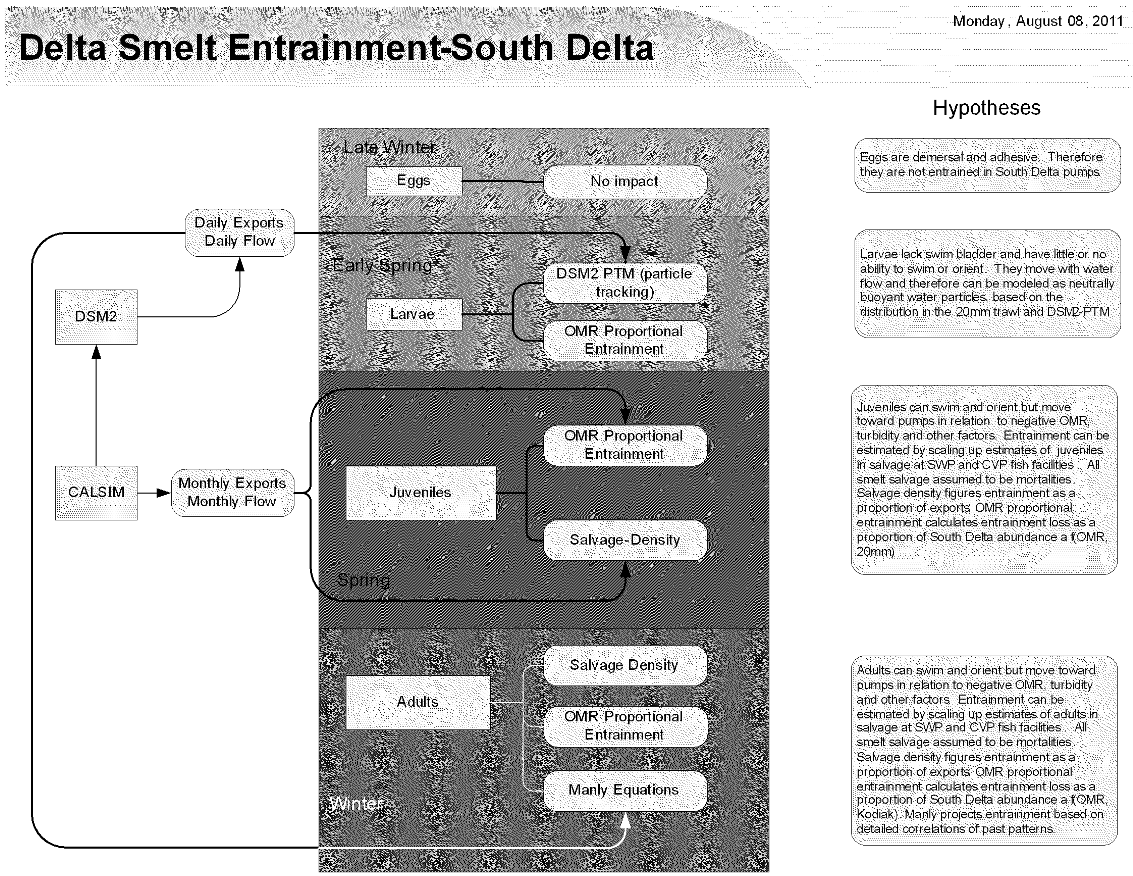


Figure A-14. A Generalized Scheme for Analysis of Delta Smelt Entrainment at SWP and CVP Facilities

Larvae

Delta smelt larvae have little or no swimming ability and disperse with water flow after hatching (Bennett 2005). Without swimming ability, they are assumed to act as neutrally buoyant particles. DSM2-PTM (Particle Tracking Model) is used to model the movement of water particles in the Delta (Table A-8). The model is used to estimate the entrainment of delta smelt larvae at the south Delta pumps under baseline and conservation measure scenarios.

Juveniles and Adults

Although delta smelt in general are characterized as poor swimmers (Bennett 2005), juvenile and adult delta smelt appear to select habitat based on salinity, turbidity, and food (Feyrer and Healey 2003). Turbidity in particular seems to be a determinant of habitat suitability for delta smelt (Nobriga et al. 2008) and entrainment in the south Delta facilities may increase when OMR become turbid and delta smelt are attracted to the south Delta (Miller 2011).

Two general methods of assessing entrainment of juvenile and adult delta smelt will be used (Table A-8). The first method is Salvage-Density Method. This approach begins with the number of delta smelt collected in sampling of fish collected at the Tracy (CVP) and Skinner (SWP) fish collection sites summed by month. Samples are expanded to account for sampling proportion, efficiency, and assumed pre-salvage loss to predators. Estimated salvage is divided by the total SWP and CVP export for the month to derive an estimate of the entrainment density (fish/export volume). These monthly estimates of density are multiplied by the monthly export under a scenario derived from CALSIM II. The result is an estimate of the proportion of juvenile and adult delta smelt entrained under a modeled operational scenario (e.g., baseline or conservation measure).

The second method of estimating juvenile and adult delta smelt entrainment uses the relationship derived by Kimmerer (2008) between the monthly proportional entrainment at the south Delta pumps and flow in OMR in the same month. Delta smelt and other species are drawn into the south Delta when OMR flow is negative, i.e., flows southward, as a result of export from the south Delta pumps. Kimmerer's regression predicts entrainment from OMR flow calculated in CALSIM II for an operational scenario. More recently, Miller (2011) has suggested refinements to Kimmerer's original estimate that results in lower proportional entrainment. Kimmerer (2011) has concurred that newer data and refinements lower his original entrainment estimates. Lenny Grimaldo (pers. comm.) has suggested refinement to the OMR regressions to address the functional relationship to X2 location. This and other refinements to the calculation of proportional entrainment will be considered in developing the analytical approach to effects analysis.

Table A-8. Methods Used to Estimate Entrainment of Delta Smelt in South Delta Pumps under BDCP

	Action

	Life Stage	*Analytical Method*
Entrainment—south Delta pumps	Eggs	BPJ
Entrainment—south Delta pumps	Larvae	DSM2 PTM
Entrainment—south Delta pumps	Juvenile	OMR regressions
Entrainment—south Delta pumps	Juvenile	Salvage-density method
Entrainment—south Delta pumps	Adult	OMR regressions
Entrainment—south Delta pumps	Adult	Salvage-density method
Entrainment—south Delta pumps	Adult	Manly entrainment equations

LONGFIN SMELT

[To be developed.]

Table A-9. Methods Used to Estimate Entrainment of Longfin Smelt in South Delta Pumps under BDCP

Action	*Life Stage*	*Analytical Method*
Entrainment—south Delta pumps	Adult	Salvage-density method
Entrainment—south Delta pumps	Eggs	BPJ
Entrainment—south Delta pumps	Larvae	DSM2 PTM
Entrainment—south Delta pumps	Juvenile	OMR regressions
Entrainment—south Delta pumps	Juvenile	Salvage-density method
BPJ= best professional judgment.		

SALMON

[To be developed.]

Table A-10. Methods Used to Estimate Entrainment of Salmon in South Delta Pumps under BDCP

Action	*Species/Race*	*Life stage*	*Analytical Method*
Entrainment—south Delta pumps	Fall-/late fall–run Chinook salmon	Juvenile migrants	Delta Passage Model
			Salvage-density method
Entrainment—south Delta pumps	Spring-run Chinook salmon	Juvenile migrants	Delta Passage Model
			Salvage-density method
Entrainment—south Delta pumps	Steelhead	Juvenile migrants	Delta Passage Model
			Salvage-density method
Entrainment—south Delta pumps	Winter-run Chinook salmon	Juvenile migrants	Delta Passage Model
			Salvage-density method

SPLITTAIL

[To be developed.]

Table A-11. Methods Used to Estimate Entrainment of Splittail in South Delta Pumps under BDCP

Action	Life Stage	Analytical Method
Entrainment—south Delta pumps	Adult	Salvage-density method
Entrainment—south Delta pumps	Juvenile	Flow-salvage regression

STURGEONS

[To be developed.]

Table A-12. Methods Used to Estimate Entrainment of Sturgeon in South Delta Pumps under BDCP

Action	Species	Life Stage	Analytical Method
Entrainment—south Delta pumps	Green sturgeon	Egg/embryo	BPJ
		Larvae	BPJ
		Juvenile	Salvage-density method
Entrainment—south Delta pumps	White sturgeon	Egg/embryo	BPJ
		Larvae	BPJ
		Juvenile	Salvage-density method
BPJ= best professional judgment.			

A.2.5.5 *Food*

A.2.5.5.1 The Issue

The biological community of the Delta has undergone dramatic shifts over the last 50 years or more in response to the Land Use drivers and the introduction of nonnative fish and invertebrate species (Cohen and Carlton 1998; Kimmerer 2004; Sommer et al. 2007). In particular, the amount and type of food available to pelagic species, such as delta smelt, have been altered. Pelagic food (zooplankton) is affected by species composition and primary production both autochthonous (phytoplankton) and allochthonous (organic detritus). The lack of availability of suitable food has been implicated as an important factor in the decline of pelagic fish species, especially delta smelt (Sommer et al. 2007; Nobriga and Herbold 2009; Baxter et al. 2010). The shift in pelagic food has been tied to the invasion of the invasive competing species like the Corbula clam (Baxter et al. 2010), declines in organic detritus because of loss of tidal wetlands (Baxter et al. 2010), introduced zooplankton species (Kimmerer 2004), and the decline in phytoplankton as a result of lowered water quality (Glibert 2010).

Food supply issues in the Delta are believed to affect mainly pelagic species like delta smelt, longfin smelt, and splittail. Food has not been indicated as a limiting factor for juvenile salmon, lamprey, or sturgeon in the Delta.

A.2.5.5.2 Covered Activities

Restoration of nearshore aquatic habitats (Conservation Measures 2, 4, 5, 6, and 7) is expected to increase the amount of organic detritus delivered to open water areas that contribute to the pelagic food supply. As discussed under the Water Quality stressor, restoration of natural wetland should reduce the amount of agricultural chemicals entering the Delta.

A.2.5.5.3 Approach

Foodwebs have been extensively modeled in other ecosystems building on a rich theoretical base (Allesina et al. 2008). Tools such as EcoPath are available to construct foodweb models of large and complex ecosystems. However, foodweb modeling in the Delta is still in the early stages, and no generally recognized foodweb model is available. Because of this, a best professional judgment approach will be used that synthesizes the available information on food conditions to develop hypotheses of the impact of BDCP conservation measures on Delta pelagic food supply.

A.2.5.6 *Predation*

Predation impacts in the Delta generally are tied to piscivorous (fish-eating) fish species. Birds are likely also important predators of Delta fish species.

A.2.5.6.1 The Issue

The introduction of exotic species into the Delta has added several new piscivorous fish species such as striped bass, large- and smallmouth bass, and catfish. These introduced predators have added to a smaller number of native predatory fish such as the Sacramento pikeminnow. In addition to adding to the number of piscivorous fish species, many human activities increase the effectiveness of predators by concentrating prey or providing cover. Predation is known to be high around intake structures such as the south Delta pumps, especially in Clifton Court Forebay.

A.2.5.6.2 Covered Activities

Conservation Measure 15 calls for the direct removal of predatory fish species at locations where they tend to congregate resulting in high mortality of prey species such as delta smelt. Conservation Measure 13 addresses the removal of concentrations of SAV that is thought to provide cover and increase the effectiveness of predatory species. Construction and operation of the north Delta pumps could provide conditions that enhance predator effectiveness.

A.2.5.6.3 Approach

Like foodwebs discussed above, predator-prey relationships have been the focus of considerable modeling and analysis in ecological literature. However, in the Delta, predator concerns often focus on site-specific conditions at intakes or other structures. Few direct estimates of predation rates and effectiveness are available, although available studies support the contention that predation is especially high in Clifton Court Forebay and at other sites. No predator model is available for BDCP analysis. Because of this, a best professional judgment approach will be used that synthesizes the available information on predator distribution and effectiveness to develop hypotheses of the impact of BDCP conservation measures on predation impacts in the Delta.

A.2.5.7 Fish Populations

[Note to reviewers: there are many issues that remain to be resolved regarding population level analysis.]

The BDCP effects analysis is intended to facilitate development of a conclusion regarding the overall impacts of BDCP conservation measures on covered species. The ultimate need is for conclusions at a species or population level. This section will discuss the available life cycle analyses and methods for the "roll-up" of the effects analysis.

A.2.5.7.1 The Issue

Analyses discussed above with regard to conservation measures refer to their impacts on life stages as a result of specific actions. To roll-up the effects of covered activities and conservation measures across conservation measures, geographic areas, and life stages for a species will require a life history analysis.

A.2.5.7.2 Covered Activities

Population level analysis integrates across stressors, covered activities, and conservation measures.

A.2.5.7.3 Approach

Roll-up of BDCP impacts will involve the use of quantitative life cycle models where available as well as qualitative depictions of BDCP impacts across life stages. Quantitative life cycle models do not exist for all species, although they are available for delta smelt and for salmon. Maunder and Deriso (2011) have developed a density-dependent life cycle model for delta smelt. Hendrix (2008) has developed a baysian model for Sacramento River winter-run Chinook salmon. Using this model, Hendrix concludes that much of the variability in winter run abundance can be explained by temperature during egg incubation and as well as harvest (primarily in the ocean). The model could also address access to rearing in Yolo Bypass, the impact of exports during the outmigration period, striped bass adult abundance indices, and near-shore ocean conditions.

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